FINAL COMMITTEE REPORT

THE DESIGN, DEVELOPMENT & CERTIFICATION OF THE

BOEING 737 MAX

SEPTEMBER 2020

PREPARED FOR:

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Related Documents
Transcripts of the transcribed interviews and other documents referenced in this report can be accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

References to Senior Boeing Officials

During design, development, and certification of the 737 MAX, the following individuals held senior positions at Boeing and are referred to in Boeing documents that are linked to this report by their titles.

- Keith Leverkuhn served as Vice President (VP) and General Manager (GM) of the 737 MAX Program from April 2013 to April 2018. In Boeing documents, references to "Former 737 MAX VP/GM" are references to Mr. Leverkuhn.

- Michael Teal served as Vice President and 737 Chief Project Engineer from August 2011 to March 2017. In Boeing documents, references to "Former 737 MAX Chief Project Engineer" are references to Mr. Teal.

- Mark Forkner served as 737 Technical Pilot from 2011 to 2015 and as 737 Chief Technical Pilot from 2015 until 2018 when he left Boeing to work at Southwest Airlines. In Boeing documents, references to "Former 737 Chief Technical Pilot" are references to Mr. Forkner.

- Elizabeth "Beth" Pasztor served as Vice President (VP) of Boeing Commercial Airplanes (BCA) Safety, Security and Compliance and in this role was the ODA Lead Administrator. In Fall 2019, Ms. Pasztor became Vice President and General Manager of Product & Services Safety. In Boeing documents, references to "VP BCA Safety, Security and Compliance" are references to Ms. Pasztor.

Abbreviations

737 NG	Boeing 737 Next Generation Airplane
AAR	Airplane Assessment Report
ACO	Aircraft Certification Office
AD	Airworthiness Directive
AEG	Aircraft Evaluation Group
AFSCME	American Federation of State, County and Municipal Employees
AIA	Aerospace Industries Association
AIR	Aircraft Certification Service
AR	Authorized Representative
APA	Allied Pilots Association
ATC	Amended Type Certificate
ATP	Airline Transport Pilot
AVS	Aviation Safety Organization
BASOO	Boeing Aviation Safety Oversight Office

BCA	Boeing Commercial Airplanes
CARB	Corrective Action Review Board
CAS	Commercial Aviation Services
CBT	Computer Based Training
CEO	Chief Executive Officer
DER	Designated Engineering Representative
DOT	Department of Transportation
DR	Deficiency Report
EASA	European Union Aviation Safety Agency
EBAW	Enhanced Bank Angle Warning
ECS	Environmental Control System
EDFCS	Enhanced Digital Flight Control System
EICAS	Engine Indicating and Crew Alerting System
EU	European Union
FAA	Federal Aviation Administration
FBW	Fly-by-wire
FCC	Flight Control Computer
FCOM	Flight Crew Operations Manual
FSB	Flight Standardization Board
FTD	Fleet Team Digest
GAO	Government Accountability Office
GM	General Manager
IEEE	Institute of Electrical and Electronics Engineers
IPT	Integrated Product Team
ISS	International Space Station
JATR	Joint Authorities Technical Review
LAM	Landing Attitude Modifier
LGW	London Gatwick Airport
MCAS	Maneuvering Characteristics Augmentation System
MOM	Multi Operator Message
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NNC	Non-normal Checklist
NTSB	National Transportation Safety Board
ODA	Organization Designation Authorization
OIG	Office of Inspector General
OMB	Operations Manual Bulletin
PASS	Professional Aviation Safety Specialists
PSSA	Preliminary System Safety Assessment
QFR	Questions for the Record
RCAS	Roll Command Alerting System
R-TARA	Random Transport Airplane Risk Analysis
SCD	Specification Control Drawing
SME	Subject Matter Expert
SSA	System Description and Safety Analysis
STC	Supplemental Type Certificate
STS	Speed Trim System

SWA	Southwest Airlines
TARAM	Transport Airplane Risk Assessment Methodology
TCBI	Tutorial Computer-Based Instruction
TIA	Type Inspection Authorization
VP	Vice President

1. Introduction

-Introduction-

On the evening of March 9, 2019, Paul Njoroge was up late, tracking a flight from Toronto, Canada to Addis Ababa, Ethiopia. It was the first leg of his family's journey to visit relatives in Kenya for what was to be the trip of their lifetimes. After his family arrived safely at their layover in Addis Ababa, Mr. Njoroge went to bed, expecting to check in again the next day.

As he slept, his wife Carolyne, their three children—6-year-old Ryan, 4-year-old Kelli, and 9-month-old Rubi—and his mother-in-law, Ann, continued their journey by boarding Ethiopian Airlines flight 302 from Addis Ababa, Ethiopia, to Nairobi, Kenya. It was a crystal-clear day, but within minutes of take-off the unthinkable happened: the Boeing 737 MAX, a brand new aircraft with 157 passengers and crew members on board, began to dive back towards the ground as the pilots fought to force the plane's nose back up toward the sky. The battle did not last long. Six minutes after take-off, Ethiopian Airlines flight 302 crashed. The jet's impact left a massive crater in a field just a few miles from the airport. Not a single soul survived.

Over one year later, Mr. Njoroge testified before the U.S. House Committee on Transportation and Infrastructure that he is still haunted by the image of his young children's final moments. "I have nightmares about how they must have clung to their mother, crying, seeing the fright in her eyes as they sat there helplessly. And there was nothing I could do to save them," he said. "I miss their laughter, their playfulness, their touch."

Mr. Njoroge would soon learn that his family members were the victims of not the first, but the second Boeing 737 MAX aircraft that was involved in a catastrophic, fatal crash killing everyone on board—an extraordinary fact given the significant advances in aviation safety over the last two decades, and the fact that the 737 MAX was a newly certified aircraft.

The story of the Boeing 737 MAX was never expected to be associated with catastrophe. It was supposed to be a story of American ingenuity and technological success—a modern, more fuel-efficient airplane that had already become the manufacturing giant's best-selling jet in its storied history prior to the first MAX crash of Lion Air flight 610 in Indonesia on October 28, 2018. Ethiopian Airlines flight 302 crashed on March 10, 2019, just two years and two days after the Federal Aviation Administration (FAA) had certified the new 737 derivative aircraft as safe to fly. Clearly it was not.

The Boeing 737 MAX is now the subject of multiple investigations and lawsuits around the world and will be forever associated with the tragic deaths of 346 people killed in two separate crashes within five months of each other, as well as one rescue diver who died attempting to recover bodies from the Lion Air crash in the Java Sea.

-FINAL COMMITTEE REPORT: BOEING 737 MAX-

1. Introduction

This report concludes the U.S. House Committee on Transportation and Infrastructure's 18-month long investigation of the design, development, and certification of the 737 MAX aircraft, and related matters. The Committee's investigation has revealed multiple missed opportunities that could have turned the trajectory of the MAX's design and development toward a safer course due to flawed technical design criteria, faulty assumptions about pilot response times, and production pressures. The FAA also missed its own opportunities to change the direction of the 737 MAX based on its aviation safety mission. Boeing failed in its design and development of the MAX, and the FAA failed in its oversight of Boeing and its certification of the aircraft.

At the direction of Committee Chair Peter DeFazio and Subcommittee on Aviation Chair Rick Larsen, this report is being released to help inform the public's understanding of what went so horrifically wrong and why. Despite the sweeping and substantive problems that have been identified by this Committee's investigation as well as various other investigations, both Boeing and the FAA have suggested that the certification of the 737 MAX was compliant with FAA regulations. The fact that a compliant airplane suffered from two deadly crashes in less than five months is clear evidence that the current regulatory system is fundamentally flawed and needs to be repaired.

2. Executive Summary

-FINAL COMMITTEE REPORT: BOEING 737 MAX-
2. Executive Summary

-Executive Summary-

Technical design flaws, faulty assumptions about pilot responses, and management failures by both The Boeing Company (Boeing) and the Federal Aviation Administration (FAA) played instrumental and causative roles in the chain of errors that led to the crashes of Lion Air flight 610 in October 2018,[1] and Ethiopian Airlines flight 302 in March 2019,[2] that resulted in the tragic and preventable deaths of 346 people. Both crashes involved Boeing 737 MAX airplanes.

On March 8, 2017, the FAA granted an amended type certificate to Boeing for the 737-8 aircraft, the first of the 737 MAX family.[3] The MAX is the 4th generation 737 model airplane[4] and is the successor to the company's 737 Next Generation (NG) family of aircraft.[5] The 737 MAX was the 12th derivative model of the 737 aircraft,[6] which was first certified half a century earlier in 1967.[7] In May 2017, the 737 MAX first entered revenue passenger service with Malindo Air, a Malaysian air carrier, two months after its FAA certification.[8] Seventeen months later the 737 MAX suffered its first fatal crash.[9]

On October 29, 2018, Lion Air flight 610 flying from Soekarno–Hatta International Airport in Jakarta, Indonesia, to Depati Amir Airport in Pangkal Pinang, Indonesia, crashed into the Java Sea 13 minutes after takeoff, killing all 189 passengers and crew.[10] One Indonesian rescue diver also died

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[1] Barbara S. Peterson, "How Could a Brand New Boeing Jet Crash Without Warning?," *Popular Mechanics*, October 31, 2018, accessed here: https://www.popularmechanics.com/flight/airlines/a24405573/indonesia-boeing-737-max-jet-crash

[2] Hadra Ahmed, Norimitsu Onishi, Dionne Searcey and Hannah Beech, "Ethiopian Airlines Plane Is the 2nd Boeing Max 8 to Crash in Months," *New York Times*, March 10, 2019, accessed here: https://www.nytimes.com/2019/03/10/world/africa/ethiopian-airlines-plane-crash.html

[3] "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf

[4] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, p. 5, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[5] "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf

[6] The 737 MAX was the 12th "derivative" of the original 737-100 aircraft certified in 1967, making it the 13th 737 model produced by Boeing. See: "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf

[7] Ibid.

[8] Firdaus Hashim, "Malindo operates world's first 737 Max flight," *FlightGlobal,* May 22, 2017, accessed here: https://www.flightglobal.com/orders-and-deliveries/malindo-operates-worlds-first-737-max-flight/124109.article

[9] James Griffiths, Steve George, Kathy Quiano and Helen Regan, "Lion Air crash: Indonesia to inspect all Boeing 737 Max 8 planes," *CNN*, November 1, 2018, accessed here: https://www.cnn.com/2018/10/30/asia/lion-air-plane-crash-intl/index.html

[10] "Final KNKT.18.10.35.04 Aircraft Accident Investigation Report, PT. Lion Mentari Airlines, Boeing 737-8 (MAX); PKLQP, Tanjung Karawang, West Java, Republic of Indonesia, 29 October 2018," Komite Nasional Keselamatan Transportasi (KNKT), Republic of Indonesia, issued October 25, 2019, pp. 19-27 (hereafter referred to as: "Lion Air

during recovery efforts.[11] Less than five months later, on March 10, 2019, in strikingly similar circumstances, Ethiopian Airlines flight 302 crashed six minutes after takeoff on a flight from Addis Ababa, Ethiopia, to Nairobi, Kenya, killing all 157 passengers and crew, including eight U.S. citizens.[12]

In March 2019, within days of the crash of Ethiopian Airlines flight 302, the House Committee on Transportation and Infrastructure (Committee), under the leadership of Chair Peter A. DeFazio and Subcommittee on Aviation Chair Rick Larsen, launched an investigation into the design, development, and certification of the 737 MAX aircraft and related matters that led to these crashes.[13] Since then, the Committee has held five hearings on issues related to the 737 MAX program;[14] written 23 oversight letters, including 12 records request letters; received an estimated 600,000 pages of records from Boeing, the FAA, airlines, and others; and conducted two dozen official interviews with current Boeing and FAA employees and others. This included transcribed interviews with Michael Teal, former vice president, chief project engineer and deputy program manager of the 737 MAX program;[15] Keith Leverkuhn, former vice president and former general manager of Boeing's 737 MAX program;[16] and Ali Bahrami, the FAA's current Associate Administrator for Aviation Safety. Committee staff have also spoken with a wide range of aviation experts, engineers, software developers, and former FAA and Boeing employees. In addition, the Committee's investigation has been informed by records and information provided by numerous whistleblowers who have contacted the Committee directly with their concerns.

This report was produced by Democratic staff of the Committee and is the culmination of the Committee's investigative efforts assessing the costs, consequences, and lessons from the design, development, and certification of Boeing's 737 MAX aircraft. The report reveals several unmistakable facts. The MAX crashes were not the result of a singular failure, technical mistake, or mismanaged event. They were the horrific culmination of a series of faulty technical assumptions by Boeing's engineers, a lack of transparency on the part of Boeing's management, and grossly insufficient oversight by the FAA—the pernicious result of regulatory capture on the part of the FAA with respect to its responsibilities to perform robust oversight of Boeing and to ensure the safety of the flying public. The facts laid out in this report document a disturbing pattern of

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Flight 610 Final Aircraft Accident Investigation Report"), accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[11] "Lion Air: Indonesian rescue diver dies while searching for victims of jet crash near Jakarta," *ABC Australia*, November 3, 2018, accessed here: https://www.abc.net.au/news/2018-11-03/indonesian-rescue-diver-dies-in-lion-air-jet-crash-search/10463266

[12] "Interim Investigation Report on Accident to the B737-8(MAX) Registered ET-AVJ operated by Ethiopian Airlines on 10 March 2019," Federal Democratic Republic of Ethiopia, Ministry of Transport, Aircraft Accident Investigation Bureau, released March 9, 2020, pp. 11-18 (hereafter referred to as: "Ethiopian Airlines Flight 302 Interim Investigation Report"), accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[13] "As Part of Investigation into Boeing 737 MAX Certification Process, Committee Sends Records Requests to FAA, Boeing," Press Release, Committee on Transportation and Infrastructure, U.S. House of Representatives, April 1, 2019, accessed here: https://transportation.house.gov/news/press-releases/as-part-of-investigation-into-boeing-737-max-certification-process-committee-sends-records-requests-to-faa-boeing

[14] See: "Boeing 737 MAX Investigation," Committee on Transportation and Infrastructure, U.S. House of Representatives, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[15] In November 2017, Mr. Teal was named to the position of vice president and chief project engineer for the Boeing 777X program.

[16] In July 2018, Mr. Leverkuhn was named to the position of vice president of Supply Chain Propulsion for Boeing Commercial Airplanes. He retired from Boeing this year.

technical miscalculations and troubling management misjudgments made by Boeing. It also illuminates numerous oversight lapses and accountability gaps by the FAA that played a significant role in the 737 MAX crashes.

-The MAX Crashes-

Ethiopian Airlines, which is wholly owned by the government of Ethiopia,[17] has flourished over the last two decades as it has capitalized on a strategy to connect primary and secondary markets across the African continent with North American, European, and Asian destinations via its hub in Addis Ababa.[18] The carrier's pilot training programs and facilities have garnered praise from seasoned American pilots.[19] Before the crash of flight 302, Ethiopian Airlines' last major accident occurred in January 2010 and involved a Boeing 737-800 departing Beirut at night bound for Addis Ababa; it was determined that the flight crew likely experienced spatial disorientation during climb out over the Mediterranean Sea in the darkness, and that the crew failed to manage the flight path of the airplane and lost control, leading to an impact with the sea. All 90 passengers and crew died.[20]

Lion Air is an Indonesian airline which provides fast, inexpensive travel across the massive Indonesian archipelago.[21] Unfortunately, Lion Air has a checkered safety record and has earned a reputation among some observers of hiring inexperienced pilots and working them hard.[22] For example, before the crash of flight 610, Lion Air airplanes had been involved in 10 accidents that led to the death of 25 people since the company's founding in 1999.[23] Moreover, between 2007 and 2016, the European Union (EU) blacklisted the carrier, prohibiting it from operating into EU member states.[24]

In November 2011, Lion Air signed a $22 billion order with Boeing for 230 units of the 737—including 201 737 MAX aircraft—the largest single order in Boeing's history.[25] However, while Lion Air's business model was built around the use of the Boeing 737 and its pilots were used

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[17] "Corporate Overview," Ethiopian Airlines, accessed here: https://corporate.ethiopianairlines.com/AboutEthiopian/Overview

[18] Omar Mohammed and Maggie Fick, "Ethiopian Airlines steps up hunt for African connections," *Reuters*, November 23, 2018, accessed here: https://www.reuters.com/article/us-ethiopia-airlines-africa/ethiopian-airlines-steps-up-hunt-for-african-connections-idUSKCN1NS0X3

[19] Prepared statement of Captain Daniel F. Carey, President, Allied Pilots Association, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/CA%20Carey%20Hearing%20testimony%20.pdf

[20] See: "ASN Accident Database: ET409," Flight Safety Foundation Aviation Safety Network, accessed here: https://aviation-safety.net/database/record.php?id=20100125-0

[21] William Langewiesche, "What Really Brought Down the Boeing 737 MAX?," *The New York Times Magazine*, September 18, 2019, accessed here: https://www.nytimes.com/2019/09/18/magazine/boeing-737-max-crashes.html?action=click&module=Top%20Stories&pgtype=Homepage

[22] Ibid.

[23] "ASN Aviation Safety Database: Lion Air accidents and incidents," Flight Safety Foundation Aviation Safety Network, accessed here: https://aviation-safety.net/database/dblist.php?sorteer=datekey_desc&kind=%&cat=%&page=1&field=Operatorkey&var=5758

[24] "Lion Air," Flight Safety Foundation Aviation Safety Network, accessed here: https://aviation-safety.net/database/operator/airline.php?var=5758

[25] "Boeing, Lion Air Announce Historic Commitment for up to 380 737s," Boeing Press Release, November 17, 2011, accessed here: https://boeing.mediaroom.com/2011-11-17-Boeing-Lion-Air-Announce-Historic-Commitment-for-up-to-380-737s and Kevin Voight, "Lion Who? What record Boeing-Indonesia deal means," *CNN Business*, November 18, 2011, accessed here: https://www.cnn.com/2011/11/18/business/boeing-lion-air-indonesia-analysis/index.html

to flying the airplane, the 737 MAX contained a new feature in its flight control computer—the Maneuvering Characteristics Augmentation System (MCAS)—that has become the center of scrutiny for both MAX crashes.[26] The new system had the ability to trigger non-pilot-commanded flight control movements that could place the airplane into a dangerous nose-down attitude that challenged the pilots' ability to control the aircraft.[27] In addition, the MCAS software operated on input from one of the two angle-of-attack (AOA) sensors[28] externally mounted on the fuselage on either side of the airplane.[29]

The day before the crash of Lion Air flight 610, a mechanic in Denpasar, Indonesia, replaced the AOA sensor on the left side of the accident airplane, prior to its 90-minute flight from Denpasar to Jakarta.[30] The mechanic used a refurbished AOA sensor that had previously been used on a Boeing 737-900ER (NG) aircraft operated by Lion Air's Malaysian sister company, Malindo Air,[31] and rebuilt in late 2017 by Xtra Aerospace in Miramar, Florida.[32]

On the flight to Jakarta, MCAS activated based on an erroneous reading from the newly installed AOA sensor and commanded the airplane's horizontal stabilizer[33] to push the nose down while the pilots struggled against it to stabilize the airplane.[34] In this case, a third "deadheading" pilot who occupied the jump seat inside the flight deck[35] recognized what was occurring and provided

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[26] Chris Brady, "Maneuvering Characteristics Augmentation System (MCAS)," The Boeing 737 Technical Guide, Updated April 18, 2020, accessed here: http://www.b737.org.uk/mcas.htm

[27] Ibid.

[28] Angle of Attack (AOA) sensors are sometimes referred to as AOA vanes. Throughout this report we refer to them as AOA sensors. See: "Angle of Attack (AOA) Systems," UTC Aerospace Systems, accessed here: https://utcaerospacesystems.com/wp-content/uploads/2018/04/Angle-of-Attack-AOA-Systems.pdf and "Angle of Attack Vane," Basic Air Data, accessed here: https://www.basicairdata.eu/knowledge-center/design/angle-of-attack-vane

[29] Ibid.

[30] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. 36, 174, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[31] Ibid., pp. 37-38.

[32] In October 2019, the FAA issued an order revoking Xtra Aerospace, LLC's repair station certificate. According to the FAA, which launched an investigation of the company after the Lion Air crash, it "determined that from November 2009 until May 2019, Xtra failed to complete and retain records in accordance with procedures in its repair station manual to support parts on its capability list. The company also did not substantiate that it had adequate facilities, tools, test equipment, technical publications, and trained and qualified employees to repair parts on its capability list." See: "FAA Revokes Repair Station Certificate of Xtra Aerospace of South Florida," Press Release, Federal Aviation Administration (FAA), October 25, 2019, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24314 and Dominic Gates, "FAA shuts down Florida repair firm that supplied faulty Lion Air sensor on Boeing 737 MAX," *Seattle Times*, October 25, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-shuts-down-revokes-certificate-of-florida-repair-firm-that-supplied-faulty-lion-air-sensor/

[33] The horizontal stabilizer is a movable part at the back of the aircraft that provides stability for the aircraft by pitching the plane up or down, to keep it flying straight. Because of the faulty AOA readings MCAS erroneously tried to push the nose of the aircraft down. See: https://howthingsfly.si.edu/ask-an-explainer/what-horizontal-stabilizer-modern-commercialairplanes#:~:text=What%20is%20a%20horizontal%20stabilizer%20in%20modern%20commercial%20airplanes%3F,-A%3A&text=A%20horizontal%20stabilizer%20is%20a,down%20motion%2C%20of%20the%20aircraft.

[34] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. 174-176, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[35] Throughout this report we use the term "flight deck" instead of "cockpit" in regard to the 737 MAX. According to Aviation Stack Exchange, "A cockpit is a hole with a seat that you strap into for the entire flight. A flight deck is a larger version of a cockpit, where you can at least leave your seat and walk behind it." Access here:

instructions to the two active pilots that enabled them to regain control of the airplane and fly it safely to Jakarta by depressing two "stabilizer trim cutout" switches, thereby removing electrical power from the flight control that MCAS was erroneously activating.[36]

Upon landing in Jakarta, the captain made entries in the airplane's maintenance log about cautions and warnings that appeared during the flight. However, he did not report the flight crew's use of the stabilizer trim cutout switches to address the unexpected horizontal stabilizer movement.[37]

On the following day, October 29, 2018, Lion Air flight 610 departed Jakarta. Again, the AOA sensor provided inaccurate information to the flight control computer which triggered MCAS to move the horizontal stabilizer which pushed the airplane's nose down.[38] This occurred more than 20 times as the pilots fought MCAS while struggling to maintain control of the aircraft.[39] Unfortunately, because the previous flight crew did not document its use of the stabilizer trim cutout switches to address the same condition, the new flight crew did not have an important piece of information that could have helped them to identify and respond to the problem.[40] Amid a cacophony of confusing warnings and alerts on the flight deck, the horizontal stabilizer ultimately forced the airplane into a nose-down attitude from which the pilots were unable to recover.[41]

Nearly five months later, on March 10, 2019, once again a faulty AOA sensor and subsequent triggering of MCAS led to the downing of Ethiopian Airlines flight 302. As opposed to the Lion Air accident airplane on which cautions and warnings on its earlier flights had given some indication of a problem, the 737 MAX operated by Ethiopian Airlines had no known technical troubles.[42] However, after a normal takeoff, the left AOA sensor began producing erroneous readings.[43] Over the approximately six minutes that Ethiopian Airlines flight 302 was airborne following its departure from Addis Ababa, Ethiopia, MCAS triggered four times as a result of the false AOA readings and caused the airplane's horizontal stabilizer to force the airplane into a nose-

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https://aviation.stackexchange.com/questions/66094/cockpit-vs-flight-deck#:~:text=A%20cockpit%20is%20a%20hole,the%20top%20of%20the%20ship

[36] Ibid.

[37] According to the "Lion Air Flight 610 Final Aircraft Accident Investigation Report," p. 176, the captain reported problems experienced during the flight that had been displayed in messages on the Primary Flight Display and overhead flight controls panel. These problems were the IAS DISAGREE (indicated airspeed disagree) and ALT DISAGREE (altitude disagree) warnings and the illumination of the FEEL DIFF PRESS (feel differential pressure) light. The captain did not mention the activation of the stick shaker or the runaway stabilizer and the use of the STAB TRIM CUTOUT guarded switches that disabled MCAS and caused the flight crew to use manual trim for the majority of the flight and the landing.

[38] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," p. xviii, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[39] Ibid., pp. 19-28, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and Sinead Baker, "This timeline shows exactly what happened on board the Lion Air Boeing 737 Max that crashed in less than 13 minutes, killing 189 people," *Business Insider*, October 29, 2019, accessed here: https://www.businessinsider.com/lion-air-crash-timeline-boeing-737-max-disaster-killed-189-2019-10

[40] Ibid.

[41] Ibid.

[42] "Ethiopian Airlines Flight 302 Interim Investigation Report," pp. 130-132, accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[43] Ibid.

down attitude from which the pilots were unable to recover.[44] Faulty AOA data that erroneously triggered MCAS to repeatedly activate played critical roles in both MAX crashes.

There have been some allegations made against both Lion Air and Ethiopian Airlines regarding poor maintenance and even cover-ups. For example, investigators determined that photos provided by the Lion Air mechanic that purported to document the AOA sensor repair on the accident airplane depicted a different airplane and dismissed the photos as invalid evidence.[45] In addition, a whistleblower with knowledge of Ethiopian Airlines' actions in the aftermath of the March 2019 crash alleged that staff of the carrier accessed the airplane's maintenance records the day after the accident.[46] Such action is contrary to protocols that call for records to be immediately sealed following a crash.[47] However, while it is not known how, if at all, the records were altered, the whistleblower contends that this action was part of a pattern of faulty repairs and erroneous records that call into question the reliability of Ethiopian Airlines' maintenance practices.[48]

In addition to maintenance concerns, some negative aspersions have arisen about the abilities of the pilots who commanded the ill-fated Lion Air and Ethiopian Airlines flights. While Lion Air has a reputation for hiring inexperienced pilots and quickly promoting them, the 31-year-old captain of Lion Air flight 610 had accumulated over 5,100 hours of flight time on Boeing 737 airplanes, and the 41-year-old first officer had more than 4,200 hours on Boeing 737 models, indicating that they were seasoned pilots.[49] Further, while the 29-year-old captain of Ethiopian Airlines flight 302 had reportedly not received training on the airline's 737 MAX simulator—even though Ethiopian Airlines was one of the first airlines worldwide to purchase a 737 MAX specific simulator[50]—the young pilot had amassed over 5,500 flying hours on Boeing 737 airplanes, including 103 hours on the 737 MAX.[51] Even the 25-year-old first officer of flight 302—who was the least experienced of the pilots—had accumulated 207 hours flying Boeing 737 airplanes since obtaining his commercial pilot's license in December 2018, just three months before the fatal crash.[52]

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[44] Ibid.
[45] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," p. 185, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf
[46] Bernard Condon, "Whistleblower complaint alleges corruption in Ethiopian Airlines," *USA Today*, October 7, 2019, accessed here: https://www.usatoday.com/story/news/2019/10/07/ethiopian-airlines-whistleblower-alleges-corruption-after-737-crash/3898991002
[47] Ibid.
[48] Ibid.
[49] William Langewiesche, "What Really Brought Down the Boeing 737 MAX?" *The New York Times Magazine*, September 18, 2019, accessed here: https://www.nytimes.com/2019/09/18/magazine/boeing-737-max-crashes.html?action=click&module=Top%20Stories&pgtype=Homepage and "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. 28-30, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf
[50] Selam Gebrekidan, "Ethiopian Airlines Had a Max 8 Simulator, but Pilot on Doomed Flight Didn't Receive Training On It," *New York Times,* March 20, 2019, accessed here: https://www.nytimes.com/2019/03/20/world/africa/ethiopian-airlines-boeing.html
[51] "Ethiopian Airlines Flight 302 Interim Investigation Report," pp. 18-21, accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf
[52] Ibid.

Addressing the qualifications of these pilots at a June 2019 Subcommittee on Aviation hearing, Captain Dan Carey, a 35-year career pilot and then president of the Allied Pilots Association, which represents 15,000 American Airlines pilots, said in his written statement:

> To make the claim that these accidents would not happen to U.S.-trained pilots is presumptuous and not supported by fact. Vilifying non-U.S. pilots is disrespectful and not solution-based, nor is it in line with a sorely needed global safety culture that delivers one standard of safety and training. Simply put, Boeing does not produce aircraft for U.S. pilots vs. pilots from the rest of the world.[53]

Retired airline captain Chesley B. "Sully" Sullenberger III, who landed U.S. Airways flight 1549 on the Hudson River in 2009 saving all 155 people on board in what came to be known as the "Miracle on the Hudson," also testified at that hearing. He offered similar sentiments about the qualifications of these pilots as part of his remarks about the two crashes.[54] In his prepared testimony Captain Sullenberger wrote:

> These crashes are demonstrable evidence that our current system of aircraft design and certification has failed us… It is obvious that grave errors were made that have had grave consequences, claiming 346 lives… Accidents are the end result of a causal chain of events, and in the case of the Boeing 737 MAX, the chain began with decisions that had been made years before, to update a half-century-old design… We owe it to everyone who flies, passengers and crews alike, to do much better than to design aircraft with inherent flaws that we intend pilots will have to compensate for and overcome. Pilots must be able to handle an unexpected emergency and still keep their passengers and crew safe, but we should first design aircraft for them to fly that do not have inadvertent traps set for them.[55]

For two brand-new airplanes, of a brand-new derivative model, to crash within five months of each other was extraordinary given significant advances in aviation safety over the last two decades.[56] While certain facts and circumstances surrounding the accidents differed, a common

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[53] Prepared statement of Captain Daniel F. Carey, President, Allied Pilots Association, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/CA%20Carey%20Hearing%20testimony%20.pdf

[54] Robert D. McFadden, "Pilot Is Hailed After Jetliner's Icy Plunge," *New York Times*, January 15, 2009, accessed here: https://www.nytimes.com/2009/01/16/nyregion/16crash.html and Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/status-of-the-boeing-737-max-stakeholder-perspectives

[55] Prepared statement of Chesley B. "Sully" Sullenberger III, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/Sully%20Sullenberger%20Testimony.pdf

[56] See: "Fact Sheet – Out Front on Airline Safety: Two Decades of Continuous Evolution," Federal Aviation Administration, August 2, 2018, accessed here: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22975; "Safety Record of U.S. Air Carriers," Airlines for America, accessed here: https://www.airlines.org/dataset/safety-

component in both of the accident airplanes was the new flight control feature: MCAS. Boeing developed MCAS to address stability issues in certain flight conditions induced by the plane's new, larger engines, and their relative placement on the 737 MAX aircraft compared to the engines' placement on the 737 NG.[57] On March 13, 2019, the FAA grounded the 737 MAX three days after the Ethiopian Airlines crash, following similar actions taken by China, the EU, and Canada, among others.[58] Despite optimistic predictions at the time—that a simple software fix for MCAS would allow the 737 MAX to return quickly to service[59] —the aircraft has been grounded for 18 months, with even more, newly discovered safety issues emerging since.[60] *(See "New Issues Emerge" below).*

This report identifies the key technical flaws and management failures the Committee has discovered at both Boeing and the FAA during its investigation of the design, development, and certification of the 737 MAX, and related issues. We anticipate that the factual evidence our investigation has uncovered and the findings we present in this report will help the Members of the Committee as they consider legislative actions to (1) rectify the problems our investigation has revealed, (2) create a more robust FAA oversight structure and improved certification process, and (3) enhance the safety of the flying public.

-Investigative Themes-

The Committee's investigative findings identify five central themes that affected the design, development, and certification of the 737 MAX and FAA's oversight of Boeing. Acts, omissions, and errors occurred across multiple stages and areas of the development and certification process of the 737 MAX. These themes are present throughout this report. They include:

1) Production Pressures. There was tremendous financial pressure on Boeing and the 737 MAX program to compete with Airbus' new A320neo aircraft.[61] Among other things, this pressure resulted in extensive efforts to cut costs, maintain the 737 MAX program schedule, and avoid

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record-of-u-s-air-carriers; and "Air Traffic By the Numbers," (Commercial Flight and Available Seat Mile (ASM) Trends), Federal Aviation Administration, June 2019, accessed here: https://www.faa.gov/air_traffic/by_the_numbers/media/Air_Traffic_by_the_Numbers_2019.pdf

[57] Ralph Vertabedian, "How a 50-year-old design came back to haunt Boeing with its troubled 737 MAX jet," *Los Angeles Times,* March 15, 2019, accessed here: https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html

[58] "Emergency Order of Prohibition: Operators of Boeing Company Model 737-8 and Boeing Company Model 737-9 Airplanes," Federal Aviation Administration, Department of Transportation, March 13, 2019, accessed here: https://www.faa.gov/news/updates/media/Emergency_Order.pdf and Luz Lazo, Michael Laris, Lori Arantani and Damian Paletta, "FAA's emergency order grounding Boeing jets came after the agency identified similarities between crashes in Ethiopia, Indonesia," *Washington Post*, March 13, 2019, accessed here: https://www.washingtonpost.com/local/trafficandcommuting/canada-grounds-boeing-737-max-8-leaving-us-as-last-major-user-of-plane/2019/03/13/25ac2414-459d-11e9-90f0-0ccfeec87a61_story.html

[59] See: Dawn Gilbertson, "Boeing 737 MAX: How will airlines convince skittish passengers it's safe to fly again," *USA Today*, April 7, 2019, accessed here: https://www.usatoday.com/story/travel/flights/2019/04/06/boeing-737-max-8-passengers-return-airlines-safety-crashes-fix-airplanes/3376865002/ and Sam Roecker, "Boeing 737 MAX MCAS Update Ready For Certification," *Simple Flying*, April 18, 2019, accessed here: https://simpleflying.com/boeing-737-max-update-complete

[60] Natalie Kitroeff and David Gelles, "It's Not Just Software: New Safety Risks Under Scrutiny on Boeing's 737 Max," *New York Times*, January 29, 2020, accessed here: https://www.nytimes.com/2020/01/05/business/boeing-737-max.html

[61] David Gelles, Natalie Kitroeff, Jack Nicas, and Rebecca R. Ruiz, "Boeing Was 'Go, Go, Go' to Beat Airbus With the 737 MAX," *New York Times*, March 29, 2019, accessed here: https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html

slowing the 737 MAX production line. The Committee's investigation has identified several instances where the desire to meet these goals and expectations jeopardized the safety of the flying public.

2) Faulty Design and Performance Assumptions. Boeing made fundamentally faulty assumptions about critical technologies on the 737 MAX, most notably with MCAS. Based on these faulty assumptions, Boeing permitted MCAS—software designed to automatically push the airplane's nose down in certain conditions—to activate on input from a single angle of attack (AOA) sensor. It also expected that pilots, who were largely unaware that the system existed, would be able to mitigate any potential malfunction. Boeing also failed to classify MCAS as a safety-critical system, which would have attracted greater FAA scrutiny during the certification process. The operation of MCAS also violated Boeing's own internal design guidelines related to the 737 MAX's development which stated that the system should "not have any objectionable interaction with the piloting of the airplane" and "not interfere with dive recovery."[62]

3) Culture of Concealment. In several critical instances, Boeing withheld crucial information from the FAA, its customers, and 737 MAX pilots. This included concealing the very existence of MCAS from 737 MAX pilots[63] and failing to disclose that the AOA Disagree alert was inoperable on the vast majority of the 737 MAX fleet,[64] despite having been certified as a standard aircraft feature.[65] The AOA Disagree alert is intended to notify the crew if the aircraft's two AOA sensor readings disagree, an event that can occur if one sensor is malfunctioning or providing faulty AOA data. Boeing not only concealed this information from both the FAA and pilots, but also continued to deliver MAX aircraft to its customers knowing that the AOA Disagree alert was inoperable on most of these aircraft. Further, Boeing concealed internal test data it had that revealed it took a Boeing test pilot more than 10 seconds to diagnose and respond to uncommanded MCAS activation[66] in a flight simulator, a condition the pilot found to be "catastrophic[.]"[67] While it was not required to share this information with the FAA or Boeing customers, it is inconceivable and inexcusable that

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[62] Boeing Coordination Sheet, Revision G, June 11, 2018, TBC-T&I 30584 – 30592 at TBC-T&I 30588, at p. 170, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[63] Benjamin Shang, "Boeing's CEO explains why the company didn't tell 737 Max pilots about the software system that contributed to 2 fatal crashes," *Business Insider*, April 29, 2019, accessed here: https://www.businessinsider.com/boeings-ceo-on-why-737-max-pilots-not-told-of-mcas-2019-4

[64] Alan Levin, "Boeing Failure to Fix 737 Max Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty

[65] See: Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, July 11, 2019, (On file with the Committee), and Julie Johnsson, Ryan Beene and Mary Schlangenstein, "Boeing Held Off for Months on Disclosing Faulty Alert on 737 Max," *Bloomberg*, May 5, 2019, accessed here: https://www.bloomberg.com/news/articles/2019-05-05/boeing-left-airlines-faa-in-dark-on-737-alert-linked-to-crash

[66] The Maneuvering Characteristics Augmentation System (MCAS) was designed to activate automatically without any pilot command. To the extent this report uses the term "uncommanded" in connection with MCAS activation, it is for consistency with Boeing's own Functional Hazard Assessments which measured "Uncommanded MCAS function operation to pilot reaction[,]" and determined that a pilot reaction time of greater than 10 seconds could be "catastrophic[.]"

[67] "Coordination Sheet, Subject: 737 MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, BATES Number TBC-T&I 29160 – 29166 at p. 164, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Boeing withheld this information from them. It also argues strongly for a disclosure requirement. Federal guidelines assume pilots will respond to this condition within four seconds.[68]

4) Conflicted Representation. The Committee found that the FAA's current oversight structure with respect to Boeing creates inherent conflicts of interest that have jeopardized the safety of the flying public. The Committee's investigation documented several instances where Boeing Authorized Representatives (ARs)—Boeing employees who are granted special permission to represent the interests of the FAA and to act on the agency's behalf in validating aircraft systems and designs' compliance with FAA requirements—failed to disclose important information to the FAA that could have enhanced the safety of the 737 MAX aircraft.[69] In some instances, a Boeing AR raised concerns internally in 2016 but did not relay these issues to the FAA, and the concerns failed to result in adequate design changes. Some of the issues that were raised by the AR and not thoroughly investigated or dismissed by his Boeing employees, such as concerns about repetitive MCAS activation and the impact of faulty AOA data on MCAS, were the core contributing factors that led to the Lion Air and Ethiopian Airlines crashes more than two years later.

5) Boeing's Influence Over the FAA's Oversight Structure. Multiple career FAA officials have documented examples where FAA management overruled a determination of the FAA's own technical experts at the behest of Boeing. In these cases, FAA technical and safety experts determined that certain Boeing design approaches on its transport category aircraft were potentially unsafe and failed to comply with FAA regulations, only to have FAA management overrule them and side with Boeing instead.[70] These incidents have had a detrimental impact on the morale of FAA's technical and subject matter experts that compromises the integrity and independence of the FAA's oversight abilities and the safety of airline passengers. A recent draft internal FAA "safety culture survey" of employees in the agency's Aviation Safety Organization (AVS) drew similar conclusions. "Many believe that AVS senior leaders are overly concerned with achieving the business-oriented outcomes of industry stakeholders and are not held accountable for safety-related decisions," the survey observed.[71]

These five recurring themes point to a troubling pattern of problems that affected Boeing's development and production of the 737 MAX and the FAA's ability to provide appropriate

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[68] JATR Report p.14, accessed here: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf and FAA Advisory Circular 25.1329-1C, October 27, 2014, p. 78, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C.pdf

[69] For example, a June 7, 2013, email described an internal Boeing meeting that showed an AR concurred with Boeing's plan to describe MCAS as part of the speed trim function to avoid greater FAA certification requirements and pilot training impacts. See: Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[70] "Amid Committee's Ongoing Investigation into the Certification of the 737 MAX, Chairs DeFazio and Larsen Raise New and Serious Concerns to FAA About Other Safety-related Issues," Press Release, Committee on Transportation and Infrastructure, U.S. House of Representatives, November 7, 2019, (hereafter referenced as T&I Committee Press Release, November 7, 2019) accessed here: https://transportation.house.gov/news/press-releases/amid-committees-ongoing-investigation-into-the-certification-of-the-737-max-chairs-defazio-and-larsen-raise-new-and-serious-concerns-to-faa-about-other-safety-related-issues-

[71] "Safety Culture Assessment Report," Federal Aviation Administration, Aviation Safety Organization (AVS), conducted and prepared by The MITRE Corporation, (DRAFT) February 28, 2020, (Hereafter referred to as "FAA Safety Culture Survey"). (On file with the Committee).

oversight of Boeing and the agency's certification process. These issues must be addressed by both Boeing and the FAA in order to correct poor certification practices that have emerged, reassess key assumptions that affect safety, and enhance transparency to enable more effective oversight.

-Investigative Findings-

Listed below are the Committee's investigative findings grouped into six distinct categories: 1) FAA oversight, 2) Boeing production pressures, 3) Maneuvering Characteristics Augmentation System (MCAS), 4) AOA Disagree alert, 5) 737 MAX pilot training, and 6) Post-accident responses by Boeing and the FAA.

FAA Oversight –*The FAA failed to ensure the safety of the traveling public.*

- The FAA's recent draft "safety culture survey" has made it clear that the agency is struggling to effectively fulfill its core regulatory and oversight mission to enhance aviation safety. According to the survey results, 49 percent of the FAA employees responding said they believe "safety concerns/incidents" will not be addressed, 43 percent believe the FAA delegates too many certification activities to industry and 34 percent said "fear of retribution" is one reason employees don't report safety issues.[72] These results correspond with many of the Committee's own investigative findings.

- Excessive FAA delegation to Boeing has eroded FAA's oversight capabilities.

- Boeing's Authorized Representatives (ARs) may be impaired from acting independently.

- A 2016 Boeing internal survey of its ARs, who are supposed to represent the interests of the FAA, conducted at the height of the 737 MAX's certification activities, and provided to the Committee from a whistleblower, found that 39 percent of Boeing ARs that responded perceived "undue pressure" and 29 percent were concerned about consequences if they reported potential "undue pressure."[73]

- The Committee has documented four instances in Boeing's 737 MAX program where Boeing ARs failed to represent the interests of the FAA in carrying out their FAA-delegated functions. In one instance, in 2013, an AR concurred on a decision **not** to emphasize MCAS as a "new function" because of Boeing's fears that doing so would increase "costs"[74] and lead to "a greater certification and training impact" on the 737 MAX program.[75] The Committee has no evidence that the AR shared this information with the FAA. In addition, the Committee found no evidence that any of the four Boeing ARs who knew that Boeing

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[72] Ibid.
[73] "Undue Pressure: Key Learnings and Next Steps," Boeing Commercial Airplanes, November 2016, at p. 145, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[74] Boeing "ITRACS" report, "Title: MCAS/Speed Trim," 37MAXFCI-PDR_AI22, Item entered: May 21, 2013, Item closed: June 27, 2013, BATES Number TBC-T&I 549172 – 548173. (On file with the Committee).
[75] Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," Sent: June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf (The issues surrounding this June 2013 meeting regarding MCAS, and Boeing's position on it, are discussed at length in the *MCAS section* of this report).

had evidence demonstrating that in 2012 it took a Boeing test pilot more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator, a condition the pilot found to be "catastrophic[,]" informed the FAA of this critical information. In 2016, a Boeing AR also raised concerns regarding the ability of MAX pilots to respond to repetitive MCAS activation and the impact of faulty AOA data on MCAS. Those concerns were not properly addressed, and the AR did not inform the FAA of the concerns. The Committee also discovered that one AR who was aware that Boeing knowingly delivered aircraft with inoperable AOA Disagree alerts to its customers in 2017 and 2018 took no action to inform the FAA.

- Not all of these instances violated FAA regulations or guidance. However, every one of them indicates that Boeing ARs are not communicating fundamentally important information about safety, certification or conformity-related issues to the FAA that could drastically enhance the agency's oversight functions and greatly improve its understanding of potential safety issues on aircraft it is obligated to certify as safe.

- FAA management has undercut the authority and judgment of its own technical experts and sided with Boeing on design issues that failed to adequately address safety issues and appear to have violated FAA regulations or guidance, in some instances. These issues go beyond the 737 MAX program. The Committee is aware of at least one example where FAA technical experts were overruled by FAA management regarding a lightning protection safety feature on another Boeing aircraft, the 787 Dreamliner.[76]

- The FAA's oversight was hampered by poor, disjointed FAA communication among the agency's own internal offices responsible for certifying new critical 737 MAX systems, such as MCAS. This lack of information impeded the ability of FAA employees to make fully informed decisions about the MAX. From FAA leadership down, ineffective communication and lack of coordination on key certification and safety issues jeopardized the safety of the flying public.

- The FAA failed to fully exercise its oversight authority and this failure adversely affected safety. The agency did not ask enough questions or sufficiently scrutinize Boeing responses regarding critical certification-related issues involving pilot training and technical design.

- The FAA has, for instance, as of the publishing of this report, failed in its duty to hold Boeing accountable for delivering airplanes with non-functioning AOA Disagree alerts that Boeing knew were inoperable.[77] According to then-Acting FAA Administrator Dan Elwell, Boeing was required to deliver airplanes with functioning AOA Disagree alerts because they were part of the 737 MAX's approved type design.[78]

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[76] T&I Committee Press Release, November 7, 2019, accessed here: https://transportation.house.gov/news/press-releases/amid-committees-ongoing-investigation-into-the-certification-of-the-737-max-chairs-defazio-and-larsen-raise-new-and-serious-concerns-to-faa-about-other-safety-related-issues-

[77] Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, July 11, 2019, (On file with the Committee).

[78] Ibid.

- Boeing received an FAA exception to allow the company to **not** install on the 737 MAX an Engine Indicating and Crew Alerting System (EICAS)—a system common in newly type certificated aircraft since 1982 that displays for pilots aircraft system faults and failures and helps pilots prioritize their response to multiple or simultaneous indications, warnings, and alerts. The FAA accepted Boeing's argument about the impracticality and the economic expense of installing EICAS on the 737 MAX.[79] The 737 family, including the 737 MAX, is the only Boeing commercial aircraft line that does not have an EICAS installed, which may have helped to alleviate pilot confusion in both the Lion Air and Ethiopian Airlines accidents.[80]

Boeing Production Pressure – ***Costs, schedule, and production pressures at Boeing undermined safety of the 737 MAX.***

- Schedule pressure was visible to all Boeing employees working on the 737 MAX program.

- To emphasize the significance of the 737 MAX program's schedule to Boeing employees, the Committee learned that senior program officials kept a "countdown clock" in their conference room. Keith Leverkuhn, the former Vice President and General Manager of the MAX program, described the clock as an "excitement generator" for Boeing's staff. But he also acknowledged it was to remind staff about the MAX's schedule. "One of the mantras that we had was the value of a day," he said, "and making sure that we were being prudent with our time, that we were being thorough, but yet, that there was a schedule that needed to be met…."[81] He said the countdown clock was used to mark two major milestones: power on, when the MAX was powered up for the first time in the factory, and first flight.[82]

- In 2012, in order to lower costs of the 737 MAX program, Boeing reduced the work hours involved in avionics regression testing on the 737 MAX by 2,000 hours. It also examined other reductions to save costs, including a reduction to flight test support by 3,000 hours and a reduction to the engineering flight deck simulator (E-CAB) by 8,000 hours.[83]

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[79] See: "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf; Boeing slide presentation to FAA, "BCA Airplane Programs Organization Designation Authorization (ODA) Technical Review Board 737 MAX Impractical Exception Proposal – Flight Crew Alerting, 25.1322(b)(2), (b)(3), (c)(2), (d)(1), and (d)(2)," June 7, 2013, FAA-DEFAZIO-000032891 (On file with the Committee); and Dominic Gates, Steve Miletich, & Lewis Kamb, "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts

[80] Dominic Gates, Steve Miletich, & Lewis Kamb, "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts

[81] Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[82] Ibid.

[83] Boeing internal power-point presentation, "FCOI Model Leads Meeting – 737 MAX," July 12, 2012, TBC-T&I 011072 - 011073 (On file with the Committee).

- In 2013, a Boeing engineer raised the issue of installing on the 737 MAX a synthetic airspeed indicator—a computer-based indicator of speed that can be compared to actual airspeed measures—as had been done on the 787 Dreamliner. However, this request was rejected by Boeing management due to cost concerns and because adding synthetic airspeed could have jeopardized the 737 MAX program's directive to avoid pilot simulator training requirements.[84]

- The Committee has learned that to thank him for keeping to the MAX's production schedule, Boeing gave Michael Teal, the former Chief Project Engineer on the 737 MAX program, restricted stock options after the airplane's first flight in 2016 to show its appreciation for his work.[85]

- In June 2018, Ed Pierson, a senior Boeing plant supervisor at the company's Renton, Washington 737 MAX production factory, emailed Scott Campbell, the 737 General Manager, requesting a meeting about "safety concerns."[86] Mr. Pierson described multiple concerns about production and schedule pressures that were impacting quality control and safety issues. "As a retired Naval Officer and former Squadron Commanding Officer," wrote Pierson, "I know how dangerous even the smallest of defects can be to the safety of an airplane. Frankly right now all my internal warning bells are going off. And for the first time in my life, I'm sorry to say that I'm hesitant about putting my family on a Boeing airplane."[87]

- In July 2018, five weeks after Mr. Pierson's email, he finally met with Mr. Campbell in Mr. Campbell's office. According to Mr. Pierson's testimony to the Committee, he told Mr. Campbell that in the military they would temporarily halt production if they had the kinds of safety problems that Mr. Pierson was seeing on the MAX factory floor. Mr. Campbell allegedly responded: "The military is not a profit-making organization."[88] Rather than heeding Mr. Pierson's dire warnings and thoroughly evaluating his safety concerns, Boeing continued to ramp up production on the 737 MAX[89] and rehired retired Boeing employees

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[84] See: Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf, Natalie Kitroeff, David Gelles and Jack Nicas, "Boeing 737 Max Safety System Was Vetoed, Engineer Says," *New York Times*, October 2, 2019, (Updated 29, 2019), accessed here: https://www.nytimes.com/2019/10/02/business/boeing-737-max-crashes.html and Dominic Gates, Steve Miletich and Lewis Kamb, "Boeing rejected 737 MAX safety upgrades before fatal crashes, whistleblower says," *Seattle Times*, October 2, 2019 (Updated October 3, 2019), accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost

[85] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[86] Email from Ed Pierson to Scott A. Campbell, "Subject: Recovery Operations & Safety Concerns," Saturday, June 9, 2018 1:32 PM.

[87] Ibid.

[88] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, 116th Congress, First Session, U.S. House of Representatives, December 11, 2019, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[89] The Boeing Company, Q2 2018 Earnings Call, July 25, 2018, p. 6, accessed here: https://s2.q4cdn.com/661678649/files/doc_financials/quarterly/2018/q2/2Q18-Earnings-Call-Transcript-Final.pdf

to keep the production lines moving at the Renton plant.[90] Lion Air flight 610 crashed three months later in October 2018.

Maneuvering Characteristics Augmentation System (MCAS) – ***Boeing failed to appropriately classify MCAS as a safety-critical system, concealed critical information about MCAS from pilots, and sought to diminish focus on MCAS as a "new function" in order to avoid increased costs, and "greater certification and training impact."***

- Both Boeing and the FAA failed to appropriately designate MCAS a safety-critical system. In May 2019, then-Acting FAA Administrator Dan Elwell acknowledged this point at a hearing before the Committee.[91]

- In 2012, Boeing developed initial concepts for an MCAS annunciator to inform pilots when MCAS failed to activate, but never implemented it.[92] Instead, Boeing designed the "speed trim fail" alert to incorporate the MCAS failure functionality.[93] Human factors experts have argued that an MCAS-specific display that went beyond just indicating MCAS's "failure" could have helped to negate pilot confusion in the MAX accidents.[94]

- In June 2013, Boeing employees formulated a plan to help avoid increased "cost,"[95] and "greater certification and training impact" for the 737 MAX by describing MCAS as "an addition to [the existing] Speed Trim [system]."[96] The Boeing meeting minutes warned: "If we emphasize MCAS is a new function there may be a greater certification and training

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[90] "Boeing 737 MAX: Retired former employees come back to help with production," *Traveller,* September 12, 2018, accessed here: https://www.traveller.com.au/boeing-737-max-retired-former-employees-come-back-to-help-with-production-h157in

[91] Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, pp. 28-29, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

[92] "Preliminary Design Decision Memo," High Speed Pitch-Up, Revision A, November 8, 2012, BATES Number TBC-T&I 010920, TBC-T&I 010926, accessed at p. 119 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[93] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 20, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[94] Dr. Mica Endsley, a Committee Chair at the Human Factors and Ergonomics Society and a former Chief Scientist of the U.S. Air Force testified before the Transportation and Infrastructure Committee in December 2019. She pointed out: "It is critical that the automation mode and status be clearly and saliently displayed. In this case a display showing that the MCAS was on and each time it engaged, as well as its effect on aircraft trim, would have provided key input to the pilots as to what the system was doing. If the MCAS is overridden by the pilot and turned off, this should be displayed as well to provide clear feedback to the pilots on its state." See: Dr. Mica R. Endsley, Prepared Testimony, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification

[95] Boeing ITRACS Item, "MCAS/Speed Trim," 37MAXFCI-PDR AI22, BATES Number TBC T&I 549172-549173. (On file with the Committee).

[96] Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, at p. 93, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

impact."[97] According to the email that summarized the meeting minutes, a Boeing AR concurred with this plan.[98]

- In 2015, a Boeing AR raised the question of whether MCAS was "vulnerable to single AOA sensor failures…."[99] Despite this, the aircraft was delivered with MCAS dependent on a single AOA sensor. Boeing's decision to allow MCAS to operate off of a single AOA sensor has been roundly criticized by a wide range of aviation safety experts.[100]

- In March 2016, the General Manager of Boeing's 737 MAX program, Keith Leverkuhn, and Michael Teal, the former Chief Project Engineer on the 737 MAX program, both approved a redesign of MCAS to increase its authority to move the aircraft's stabilizer at low speed, in order to address "stall characteristics" requirements necessary for FAA certification.[101]

- Just hours after the approval for MCAS's redesign was granted, Boeing sought, and the FAA approved, the removal of references to MCAS from Boeing's Flight Crew Operations Manual (FCOM)[102]—a document that provides procedures, performance, and systems information to flight crews to enable their safe and efficient operation of the airplane.[103] As a result, 737 MAX pilots were precluded from knowing of the existence of MCAS and its potential effect on aircraft handling without pilot command. Meanwhile, the FAA officials who authorized this request remained unaware of the redesign of MCAS until **after** the crash of the Lion Air flight. Although Boeing's approval of the redesign of MCAS and its efforts to remove references to MCAS from pilot training material occurred nearly simultaneously it is unclear if these actions were coordinated.

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[97] Ibid.
[98] Ibid. (The issue regarding this June 2013 meeting, and Boeing's response to it, are discussed at length in the *MCAS section* of this report.)
[99] See Boeing internal email, AOA Sensor email string – TBC-T&I 10584-10585, December 17, 2015, p. 121, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[100] See: Peter Cohan, "MIT Expert Highlights 'Divergent Condition' Caused By 737 MAX Engine Placement," *Forbes*, April 2, 2019, accessed here: https://www.forbes.com/sites/petercohan/2019/04/02/mit-expert-highlights-divergent-condition-caused-by-737-max-engine-placement/#7c4f24d040aa; Jack Nicas, Natalie Kitroeff, David Gelles, & James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times*, June 1, 2019, accessed here: https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1; and Gregory Travis, "How the Boeing 737 Max Disaster Looks to a Software Developer," *IEEE Spectrum*, April 18, 2019, accessed here: https://spectrum.ieee.org/aerospace/aviation/how-the-boeing-737-max-disaster-looks-to-a-software-developer
[101] See: Boeing presentation, "737 MAX: SMYD (EFS) & FCC (MCAS) FT Validation, Basic Stall Characteristics," Compilation of previous presentations S&C, April 7, 2016, BATES Number TBC T&I 257428-257439, at TBC T&I 257430 (On file with Committee); Boeing presentation, "737 MAX / Stall Characteristics – Mitigation," Aero S&C, March 30, 2016, BATES Number TBC T&I 046618-046682 (On file with the Committee); and Boeing internal email, "Subject: FW: 737MAX Stall Chars Meeting Summary 3-30-16," Sent: March 30, 2016, 12:46:55 PM, BATES Number TBC T&I 257421-257422 (On file with the Committee). See also, Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020 and Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.
[102] Email from Mark Forkner to FAA, "Subject: MCAS lives in both FCCs," Sent: March 30, 2016 11:16:45 (On file with the Committee).
[103] "Development of Aircraft Operating Manuals," SKYbrary, accessed here: https://www.skybrary.aero/index.php/Development_of_Aircraft_Operating_Manuals

- After Boeing redesigned MCAS in 2016 to increase its authority to move the aircraft's stabilizer at lower speeds, Boeing failed to reevaluate the system or perform single- or multiple-failure analyses of MCAS.[104]

- In June 2016, a Boeing AR raised concerns following a test flight of the 737 MAX during which MCAS countered the pilot's attempts to trim the airplane, including concerns related to the vulnerability caused by faulty AOA readings.[105] These concerns were discounted by the AR's Boeing colleagues, particularly Boeing's test pilots.[106] However, faulty AOA data that resulted in uncommanded MCAS activation was a significant contributing factor in the crashes of both the Lion Air and Ethiopian Airlines flights.[107]

- Following the same test flight, another Boeing engineer asked if repetitive MCAS activation was a safety issue.[108] A colleague responded: "I don't think this is safety, other then (sic) the pilot could fight the MCAS input and over time find themselves in a large mistrim."[109] In both the Lion Air and Ethiopian Airlines flights, the pilots struggled to overcome MCAS, partly because of MCAS's repetitive activations that forced the airplanes into a nose-down configuration from which the pilots were unable to recover.[110]

- In a transcribed interview with Committee staff, Michael Teal, the former Chief Project Engineer on the 737 MAX program, acknowledged that when he approved the MCAS redesign in March 2016 he was unaware: 1) that MCAS operated from a single AOA sensor, 2) that MCAS could activate repeatedly, or 3) that Boeing had internal test data showing that one of its own test pilots took more than 10 seconds to react to uncommanded MCAS activation in a flight simulator, and described the results as "catastrophic."[111]

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[104] See Boeing presentation to FAA, "MCAS Development and Certification Overview," December 17, 2018, (updated and transmitted to FAA on March 1, 2019), TBC-T&I130073, TBC-T&I130111, pp. 178 - 201 at p. 198, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[105] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 10:23 AM, BATES Number TBC-T&I 246488 – TBC-T&I 246493 at TBC-T&I 246490 and Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC-T&I 246488 – TBC-T&I 246493 at TBC-T&I 246489.

[106] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Sent: Wednesday, June 15, 2016, 1:43 PM, BATES Number TBC-T&I 246488 – 246493 at TBC-T&I 246489 and Boeing internal email, "Subject: RE: Discussion of MCAS Characteristics," Sent: June 22, 2016, 1:59 PM, BATES Number TBC-T&I 292457 – 292458. (On file with the Committee).

[107] See: "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and "Ethiopian Airlines Flight 302 Interim Investigation Report," accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[108] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," Sent: Thursday, June 16, 2016, 2:49 PM, BATES Number TBC-T&I 220826 (On file with the Committee).

[109] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," Sent: June 20, 2016, 6:38:08 AM, BATES Number TBC-T&I 220826 (On file with the Committee).

[110] See: "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and "Ethiopian Airlines Flight 302 Interim Investigation Report," accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[111] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.

- Mr. Teal defended his lack of awareness of these key attributes on a system he approved saying he relied on the advice of the engineers on the MAX program. Although Mr. Teal was the program's Chief Project Engineer responsible for signing off and approving of key design decisions on the MAX, he did not actually supervise any engineers. "[Y]ou could say that none of them worked for me but all of them worked for me," he said.[112] This reporting structure contributed to an overall lack of accountability on the MAX program.

- The operating parameters of the MCAS system eventually placed on the 737 MAX aircraft violated Boeing's own internal design requirements which demanded that MCAS "not have any objectionable interaction with the piloting of the airplane" and "not interfere with dive recovery," which occurred in both 737 MAX crashes.[113]

AOA Disagree Alert – ***Boeing concealed information from the FAA, its customers, and pilots that the AOA Disagree alerts were inoperable on most of the 737 MAX fleet, despite their operation being "mandatory" on all 737 MAX aircraft. To date, FAA has failed to hold Boeing accountable for these actions.***

- Boeing has publicly blamed its software supplier for an issue that tied the AOA Disagree alert, which was supposed to be standard on all 737 MAX aircraft, to an optional AOA Indicator display,[114] the result of which was to render the AOA Disagree alert inoperable on more than 80 percent of the MAX aircraft. However, the Committee has learned that in July 2015, Boeing tested this software and failed to detect the problem.[115]

- In August 2017, five months after the 737 MAX was certified by the FAA and three months after it entered revenue service, Boeing issued a problem report to its supplier complaining that the 737 MAX's AOA Disagree alert was tied to the optional AOA Indicator and therefore was not functioning on the vast majority of the 737 MAX fleet worldwide.[116] Yet Boeing had previously approved of the version of the software that tied the AOA Disagree alert to the optional AOA Indicator display in July 2015.[117]

- Rather than immediately informing the FAA and Boeing customers about this issue when it was discovered in August 2017, and advising Boeing to fix the problem via a software update as soon as possible, a Boeing AR consented to Boeing's plan to postpone the software

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[112] Ibid.
[113] Boeing Coordination Sheet, Revision G, June 11, 2018, TBC-T&I 30584 – 30592 at TBC-T&I 30588, at p. 170, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf.
[114] "Boeing Statement on AOA Disagree Alert," Press Release, The Boeing Company, May 5, 2019, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431
[115] "AOA DISAGREE Displayed with AOA Fail Flag," Problem Report (PR) 195, PR opened: May 14, 2015, PR closed: July 29, 2015, BATES Number TBC T&I TBC 267345-267346. (On file with the Committee). (Hereafter referred to as "AOA Disagree Alert Problem Report #195").
[116] See: Boeing AOA Disagree Alert Narrative. TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267830 (On file with the Committee). and Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty
[117] Letter to Chair DeFazio and Subcommittee on Aviation Chair Larsen from attorney for Rockwell Collins, June 20, 2019, p. 9. (On file with the Committee).

update until 2020, three years later, so it could be done in conjunction with the rollout of Boeing's planned 737 MAX-10 aircraft.[118]

- Although Boeing prepared a "Fleet Team Digest" to inform its customers about the inoperable AOA Disagree alert, Boeing never sent it, keeping Boeing's customers in the dark about the inoperable alert until **after** the Lion Air crash.[119]

- Boeing's software supplier, Collins Aerospace, also falsely believed that Boeing had communicated the AOA Disagree alert issue to its 737 MAX customers.[120]

- Boeing provided Lion Air with a Flight Crew Operations Manual (FCOM) for its 737-8 MAX aircraft dated August 16, 2018, one year after learning that the AOA Disagree alert was not functioning on most 737 MAX aircraft, including those operated by Lion Air. The FCOM explained how the AOA Disagree alert was intended to work and provided absolutely no indication that Boeing was fully aware that the AOA Disagree alert on the Lion Air 737 MAX aircraft was not operational.[121] As a result, Lion Air pilots who referenced Boeing's FCOM would have falsely believed that the AOA Disagree alert was functioning properly and would reliably warn them of a malfunctioning AOA sensor. Boeing knowingly deceived these pilots and its customer airlines.

- Boeing did not acknowledge that the AOA Disagree alerts on more than 80 percent of the 737 MAX fleet were inoperative until **after** the Lion Air crash in October 2018.[122]

- By the time of the Lion Air crash, Boeing had knowingly delivered approximately 200 MAX aircraft to customers around the world with non-functioning AOA Disagree alerts.[123]

- In July 2019, then-Acting FAA Administrator Dan Elwell informed the Committee that "[a]lthough an AOA Disagree message was not necessary to meet FAA safety regulations, once it was made part of the approved type design, it was required to be installed and functional on all 737 MAX airplanes Boeing produced."[124]

- Although the AOA Disagree alert was not considered a safety critical component, Boeing knowingly delivered 737 MAX aircraft to its customers with inoperable AOA Disagree alerts that did not conform to the airplane's amended type certificate. As far as the Committee understands, the FAA has failed to take any measures whatsoever to hold Boeing

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[118] Boeing AOA Disagree Alert Narrative, TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267830 - TBC-T&I 267831. (On file with the Committee).
[119] Boeing AOA Disagree Alert Narrative, TBC-T&I 267826 – TBC-T&I 267833, at TBC-T&I 267831. (On file with the Committee).
[120] Committee staff interview with Rockwell Collins employee, September 11, 2019.
[121] Lion Air Flight Crew Operations Manual, August 16, 2018, accessed at pp. 175-177 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[122] Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty
[123] "737 MAX: Deliveries Report," The Boeing Company, accessed here: http://www.boeing.com/commercial/#/orders-deliveries
[124] Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, regarding the mandatory installation of functional AOA Disagree alerts on all Boeing 737 MAX aircraft, July 11, 2019. (On file with the Committee).

accountable for knowingly delivering aircraft with non-functioning AOA Disagree alerts to their customer airlines and failing to inform MAX pilots or the FAA that an item that was supposed to be a standard feature in the cockpit was inoperable.

737 MAX Pilot Training – ***Boeing's economic incentives led the company to a significant lack of transparency with the FAA, its customers, and 737 MAX pilots regarding pilot training requirements and negatively compromised safety.***

- Boeing had tremendous financial incentive to ensure that no regulatory determination requiring pilot simulator training for the 737 MAX was made. Under a contract signed in December 2011 with Southwest Airlines, the U.S. launch customer for the 737 MAX, Boeing was financially obligated to have discounted the price of each MAX airplane it delivered to Southwest by at least $1 million if the FAA had required simulator training for pilots transitioning from the 737 NG to the 737 MAX.[125]

- Southwest had 200 firm orders for the MAX with the option to purchase an additional 191 MAX aircraft.[126] Thus, if Boeing failed to obtain Level B (non-simulator) training requirements or less from the FAA it would have owed Southwest between $200 to nearly $400 million.[127] This helped incentivize Boeing and its leadership to forestall any simulator training for 737 MAX pilots. This had the impact of evading and averting the inclusion of at least one technology that could have affected Boeing's directive to avoid simulator training.

- In November 2012, for instance, it took a Boeing test pilot more than 10 seconds to respond to uncommanded MCAS activation during a flight simulator test, a condition the pilot found to be "catastrophic[.]"[128] The FAA has provided guidance that pilots should be able to respond to this condition within four seconds.[129] This event should have focused Boeing's attention on the need for enhanced pilot training for MAX pilots. It didn't.

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[125] See: Letter from Southwest Airlines' Drew Richardson to Chair DeFazio and Subcommittee on Aviation Chair Rick Larsen, July 26, 2019, (On file with the Committee), and David Shepardson and Tracy Rucinski, "U.S. lawmakers question Boeing's $1 mln rebate clause for Southwest 737 MAX orders," *Reuters,* October 30, 2019, accessed here: https://www.reuters.com/article/us-boeing-airplane-southwest/u-s-lawmakers-question-boeings-1-mln-rebate-clause-for-southwest-737-max-orders-idUSKBN1X92D4

[126] "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}

[127] In January 2017, Southwest had 200 firm 737 MAX orders with the option to purchase 191 additional MAX aircraft. In October 2019, one year after the Lion Air crash, Southwest had 246 firm MAX orders, 34 of its MAX aircraft were grounded and it had the option to purchase 115 additional MAX aircraft. See: "Southwest Airlines Reports Fourth Quarter And Record Annual Profit; 44th Consecutive Year Of Profitability," Southwest Airlines Company, January 26, 2017, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={55E44CBF-22E3-41F5-84EF-B3EDAB030B07}; "Southwest Corporate Fact Sheet," Southwest Airlines Company, 2020, accessed here: https://www.swamedia.com/pages/corporate-fact-sheet#fleet and "Southwest Reports Record Third Quarter Net Income And Earnings Per Share," Southwest Airlines Company, October 24, 2019, accessed here: http://www.southwestairlinesinvestorrelations.com/news-and-events/news-releases/2019/10-24-2019-112936719

[128] Internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 2:40 PM, BATES Number TBC T&I 131226 – 131227 (On file with the Committee).

[129] See: JATR Report p.14 and FAA Advisory Circular 25.1329-1C, October 27, 2014, p. 78, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C.pdf

- From 2015 to 2018, the information regarding the fact that Boeing's own test pilot took more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator leading to potentially "catastrophic" consequences was included in at least six separate internal Boeing Coordination Sheets on MCAS's requirements.[130] This indicates Boeing's keen awareness of the importance of this information.

- The Committee has found no evidence that Boeing shared this information with the FAA, its customers, or 737 MAX pilots and Boeing has confirmed to the Committee that it found no record showing it shared any of these MCAS Coordination Sheets with the FAA because they were not required to do so.

- At least four Boeing ARs were aware of these findings and never reported them to the FAA.

- One of Boeing's key goals for the 737 MAX program was that simulator-based training would not be required for pilots transitioning to the 737 MAX from the 737 NG.[131] That goal undermined appropriate pilot training requirements, hampered the development of safety features that conflicted with that goal and created management incentives to downplay the risks of technologies that jeopardized that goal.[132]

- Early in the 737 MAX program, for instance, Boeing recognized that the addition of MCAS to the pilot's flight controls system posed a risk to qualifying for Level B (non-simulator) training.[133]

- However, the chief project engineer on the MAX program told Committee staff that obtaining Level B (non-simulator) pilot training requirements from the FAA was a "design objective" of the MAX program.[134] That directive demanded that differences training for

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[130] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 – TBC T&I 191232 at TBC T&I 191231 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision C, October 19, 2015, TBC T&I 253262 - TBC T&I 253268 at TBC T&I 253267 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision E, July 5, 2016, TBC T&I 129776 - TBC T&I 129782 at TBC T&I 129782 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision F, December 20, 2017, TBC T&I 037449 - TBC T&I 037457 at TBC T&I 037457 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[131] Boeing internal email, "Subject: 737 MAX Firm Configuration Status/Help Needed," Sent: May 4, 2013 11:35 AM, BATES Number TBC-T&I 048706 – 048707, at pp. 128-129 accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[132] Ibid.

[133] Ibid.

[134] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes, May 11, 2020.

pilots transitioning from the 737 NG to the 737 MAX would be limited to 16 hours—or less—of computer based training requirements.[135]

- In July 2014, two years before the FAA made a determination regarding pilot training requirements for the 737 MAX, and at a time when the FAA was actively questioning Boeing on its presumption that no simulator training would be required, Boeing issued a press release asserting: "Pilots already certified on the Next-Generation 737 will not require a simulator course to transition to the 737 MAX."[136] Boeing made similar claims in marketing materials it provided to potential customers.[137]

- In February 2015, Boeing's 737 Chief Technical Pilot wrote that MAX simulator training would be "unrecoverable" for some Boeing customers due to the lack of simulators.[138]

- In August 2016, the FAA granted provisional approval for Level B (non-simulator) differences training requirements for pilots transitioning between the 737 NG and the 737 MAX.[139] The FAA estimated that its approved computer-based training for the MAX could be completed in approximately two hours, a drastic reduction from the 16 hours Boeing was anticipating.[140]

- The following month, in September 2016, Boeing granted its team of technical pilots the company's Commercial Aviation Services (CAS) Service Excellence Award for their role in "developing the MAX Level B [non-simulator] differences training...."[141]

- In March 2017, the month the 737 MAX was certified by the FAA, Boeing's 737 Chief Technical Pilot responded to colleagues about the prospects of 737 MAX simulator training, writing: "Boeing will not allow that to happen. We'll go face to face with any regulator who tries to make that a requirement."[142]

- In May and June 2017, as some foreign carriers asked Boeing about providing simulator training for their pilots transitioning to the 737 MAX from the 737 NG, emails show

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[135] Boeing internal email, "Subject: 737MAX Firm Configuration Status/Help Needed," May 4, 2013, (see "Differences Pilot Training" section), TBC-T&I 048706-048708, at pp. 128-130, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[136] "Boeing Selects Supplier for 737 MAX Full-Flight Simulator," Boeing Press Release, July 11, 2014, accessed here: https://boeing.mediaroom.com/2014-07-11-Boeing-Selects-Supplier-for-737-MAX-Full-Flight-Simulator

[137] Slide presentation to Ethiopian Airlines—TBC-T&I 001999– TBC T&I 002000 at TBC T&I 002018, at pp. 124-126, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[138] Boeing internal email from 737 Chief Technical Pilot to Former 737 MAX VP/GM, Former 737 MAX Chief Project Engineer and others, "Subject: HELP NEEDED Request: 737 CL Program decision, RCAS/MAX training," Friday, February 27, 2015, 3:29 PM, BATES Number TBC T&I 552664-552666 (On file with the Committee).

[139] FAA letter to The Boeing Company, "Subject: Boeing 737 MAX Pilot Qualification Plan (PQP) Gate 4," August 17, 2016, BATES Number TBC-T&I 010895. (On file with the Committee).

[140] See: "FAA Responses to Follow-Up Questions from House T&I Staff," Sent: September 6, 2019, BATES Number FAA-T&I-000031938 – 000031939 (On file with the Committee).

[141] Boeing internal email, "Subject: RE: Weekly inputs," September 21, 2016, 4:26 PM, BATES Number TBC T&I TBC-T&I 552192. (On file with the Committee).

[142] Boeing internal email, "Subject: RE: Flight Transition costs," Sent: March 28, 2017, 9:00:58 AM, accessed at p. 28 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

Boeing's 737 Chief Technical Pilot strongly opposed such training, and in one case even successfully talked a carrier out of using such training for its pilots on the 737 MAX.[143]

- In December 2017, the Chief Technical Pilot referring to his efforts to talk airlines out of the need for simulator training wrote to a Boeing colleague: "I save this company a sick amount of $$$$."[144]

- Even after the fatal Lion Air crash, Boeing maintained that its "rationale" for removing references to MCAS from the 737 MAX training manual was still "valid,"[145] and Boeing asserted that the addition of MCAS on the 737 MAX did "not affect pilot knowledge, skills, abilities, or flight safety."[146]

- After the Lion Air crash, Boeing also recommended that FAA only require Level A training on MCAS.[147] This is the training level with the fewest obligations, and would only require pilots to review printed materials that described MCAS as part of their transition from the 737 NG to the 737 MAX.[148]

- On March 1, 2019, the FAA reminded Boeing that the original level of differences training proposed in 2016 by Boeing—**before** the Lion Air crash—was Level B.[149] The FAA informed Boeing that the software changes to MCAS "may not meet the definition of Level

[143] See: Boeing internal email, "Subject: RE: 737 MAX ATB/RTL FOTB" Sent: Monday, June 5, 2018, 8:01 PM (p. 14); Boeing Email to airline customer, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Tuesday, June 6, 2017 11:01:40 AM (p. 34); Airline customer Email to Boeing, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 12:12 AM (p. 32); and Boeing internal email, "Subject: FW: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 10:01:41 AM (p. 32); accessed here (at page numbers indicated in parenthesis): https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[144] Boeing internal instant message, December 12, 2017, at p. 87, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[145] Boeing Letter to FAA's Seattle Aviation Evaluation Group (AEG), January 30, 2019—TBC-T&I 297017–297018, at pp. 134-135, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[146] Ibid.

[147] Ibid. FAA has defined five training levels, in order of increasing requirements identified as A through E, that describe acceptable training and checking methods that are appropriate to the degree of difference between the base aircraft and the variations. See: FAA Flight Standards Information Management System, 8900.1 Contents, Volume 3 General Technical Administration, Chapter 19 Flightcrew Member Training and Qualification Programs, Section 9 Safety Assurance System: Differences Training—All Training Categories, accessed here: http://fsims.faa.gov/wdocs/8900.1/v03%20tech%20admin/chapter%2019/03_019_009.htm

[148] FAA Flight Standards Information Management System, 8900.1 Contents, Volume 3 General Technical Administration, Chapter 19 Flightcrew Member Training and Qualification Programs, Section 9 Safety Assurance System: Differences Training—All Training Categories, accessed here: http://fsims.faa.gov/wdocs/8900.1/v03%20tech%20admin/chapter%2019/03_019_009.htm

[149] FAA letter to Boeing 737 Chief Technical Pilot, "Subject: Boeing 737-8 Maneuver Characteristic Augmentation System (MCAS) Evaluation Letter of Proposal RA-19-0029 FAA Response Letter," March 1, 2019, BATES Number TBC-T&I 297019 – 297020, at pp. 136-137, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

A differences" training and advised Boeing that the company's "evaluation is proceeding at risk."[150] Nine days later, Ethiopian Airlines flight 302 crashed.

Post-Accident Response - ***Both Boeing and the FAA gambled with the public's safety in the aftermath of the Lion Air crash, resulting in the death of 157 more individuals on Ethiopian Airlines flight 302, less than five months later.***

- After the Lion Air crash, Boeing and the FAA failed to take the actions needed to avert a second crash. In November 2018, days after the Lion Air crash, both Boeing and the FAA issued advisories for 737 MAX pilots that failed to even mention the existence of MCAS by name.[151] Only after receiving inquiries about MCAS from airlines did Boeing describe MCAS in a Multi Operator Message (MOM), on November 10, 2018, that went to Boeing's MAX customers but was not otherwise made public.[152]

- The FAA acknowledged to the Committee that it had drafted—and then deleted—reference to MCAS that had originally appeared in a draft of its Emergency Airworthiness Directive (AD).[153]

- There were multiple red flags and clear data points that should have informed the FAA's decision-making after the Lion Air crash. The FAA learned, for instance, that not only had Boeing failed to fix an inoperable AOA Disagree alert on more than 80 percent of the 737 MAX fleet, but that it had also decided not to inform the FAA or its customers about the non-functioning alert for more than 14 months – until **after** the Lion Air crash.[154]

- Moreover, in December 2018, the FAA received a briefing from Boeing in which the company acknowledged that prior to certification, Boeing had not evaluated the effects of a combination of failures leading to unintended MCAS activation in simulator tests nor their combined flight deck effects on pilots.[155] Boeing also acknowledged that it did not reevaluate

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[150] Ibid.

[151] Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and FAA Emergency Airworthiness Directive # 2018-23-51, November 7, 2018, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf

[152] The Boeing Company Multi Operator Message (MOM), Subject: Information – Multi-Modal Stall Warning and Pitch Augmentation Operation, MOM-MOM-18-0655-01B, November 10, 2018, p. 290, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[153] Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled: "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 243-244: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[154] Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty and "Boeing Statement on AOA Disagree Alert," Press Release, The Boeing Company, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431

[155] MCAS Development and Certification Overview—TBC-T&I 130073–130074; 130075–130117, at pp. 178-179, 180-201, at p. 185, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

its single- and multiple-failure assessments of MCAS after its engineers made design changes to the MCAS software in 2016.[156] Further, because Boeing determined that the loss of one AOA sensor followed by erroneous readings from the other AOA sensor to be extremely improbable, it did not analyze this failure scenario even though it had determined that delayed pilot reaction in this situation was "potentially catastrophic."[157]

- These issues should have raised warning signs for the FAA, but none of these issues were deemed noncompliant with FAA regulations by the FAA.[158]

- In December 2018, the FAA conducted a risk assessment based on its Transport Aircraft Risk Assessment Methodology (TARAM) and estimated that without a fix to MCAS, during the lifetime of the 737 MAX fleet, there could potentially be 15 additional fatal crashes resulting in over 2,900 deaths.[159]

- Despite that assessment, the FAA permitted the 737 MAX to continue flying while Boeing and the FAA worked on designing and validating, respectively, a fix to the MCAS software. During the period between the crashes, the FAA repeatedly justified its decision not to ground the 737 MAX saying that it did not have appropriate data to make that determination.[160] That judgment proved tragically wrong.

- In December 2019, in a transcribed interview with Committee staff, Ali Bahrami, the FAA's Associate Administrator for Aviation Safety, seemed unaware of key issues related to the 737 MAX accidents.[161] For instance, he said he had not seen Boeing's November 6, 2018 Flight Crew Operations Manual Bulletin that Boeing had provided as an update to flight crews following the Lion Air crash. He said he was not familiar with the details of FAA's post Lion Air TARAM analysis that predicted 15 more fatal accidents without a fix to MCAS over the lifetime of the MAX fleet. He was also unaware of the fact that Boeing had conducted its own tests that showed it took a Boeing test pilot 10 seconds to respond to uncommanded MCAS activation in a flight simulator, which the pilot described as "catastrophic," despite

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[156] Ibid., p. 191
[157] Ibid., pp. 191-192.
[158] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report" February 8, 2019, Prepared by: FAA AIR-860 BASOO, (Draft), Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA) (Hereafter referred to as "FAA MCAS Oversight Report (draft).") This document was reviewed remotely by Committee staff on May 1, 2020.
[159] "Quantitative Risk Assessment, Random Transport Airplane Risk Analysis (R-TARA) Version 2.42," Aircraft Certification Service, Transport Airplane Directorate (TAD), Federal Aviation Administration (FAA), FAA-DEFAZIO-000028836, part of TAD Corrective Action Review Board (CARB) Presentation Form: CARB 1- Unsafe Condition Determination," December 11, 2018, see: page 167, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[160] Robert Wall, Andrew Tangel, and Andy Pasztor, "The FAA Has No Current Plans to Ground Boeing's 737 MAX After Deadly Crash," *Wall Street Journal*, March 11, 2019, accessed here: https://www.wsj.com/articles/the-faa-has-no-current-plans-to-ground-boeings-737-max-11552341654 and Prepared Statement of Daniel K. Elwell, Acting Administrator, Federal Aviation Administration (FAA), Hearing before the Subcommittee on Aviation of the House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, p. 24, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf
[161] Committee staff transcribed interview of Ali Bahrami, Associate Administrator for Aviation Safety, Federal Aviation Administration (FAA), December 5, 2019, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

the fact that this information had been made public at a high profile Committee hearing on the 737 MAX on October 30, 2019, and widely covered by the media.[162]

- Separately, Mr. Bahrami claimed he could not recall a single conversation with Boeing officials about the MAX in between the Lion Air and Ethiopian Airlines crashes. The FAA's head of aviation safety said, "I don't recall a conversation about that between the two accidents."[163]

- Despite that, documents Boeing provided to the Committee show that recollection was not accurate. On January 24, 2019, Elizabeth ("Beth") Pasztor, Boeing's ODA Lead Administrator, and one of Boeing's most senior officials regarding FAA regulatory compliance, emailed Mr. Bahrami about setting up a phone call.[164] "I would appreciate a few minutes of your time, the topic is Lion Air," wrote Pasztor.[165] According to Mr. Bahrami's response, the two planned to speak the following day.[166] It is unclear if the call ultimately took place and if it did, what was discussed, and who else, if anyone from FAA or Boeing was on the call. However, one week after that email requesting the call with Mr. Bahrami, Ms. Pasztor's deputy wrote to the FAA's Aircraft Evaluation Group (AEG) on Ms. Pasztor's Boeing letterhead arguing that the FAA should grant Boeing Level A training for MCAS in its post Lion Air evaluation.[167]

- The Department of Transportation (DOT) has provided the Committee with substantial FAA records in response to Chair DeFazio and Subcommittee Chair Larsen's original April 2019 records request.[168] However, this process has been inexplicably slow, seemingly incomplete and it is still unclear to the Committee—17 months later—where the agency is in its response since it has repeatedly and consistently refused to provide the Committee with clear updates on the status of these requests.[169] The Senate Committee on Commerce,

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[162] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, at p. 22, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[163] Committee staff transcribed interview of Ali Bahrami, Associate Administrator for Aviation Safety, Federal Aviation Administration, December 5, 2019.

[164] Email from Vice President, Boeing Commercial Airplanes Safety, Security, and Compliance to FAA Associate Administrator for Aviation Safety, Sent: January 24, 2019, 3:48 PM, BATES Number TBC-T&I 552822. (On file with the Committee).

[165] Ibid.

[166] Email from FAA Associate Administrator for Aviation Safety to Vice President, Boeing Commercial Airplanes Safety, Security, and Compliance, "Subject: Re: Request for brief phone call," Sent: January 24, 2019, 1:01 PM, Bates Number TBC-T&I 552822. (On file with the Committee).

[167] Boeing letter from ODA Deputy Lead Administrator to FAA SEA AEG, "Subject: Boeing Response to Transport AEG letter," RA-19-00269, January 30, 2019, TBC-T&I 297017 – 297018 (On file with the Committee).

[168] See: "As Part of Investigation into Boeing 737 MAX Certification Process, Committee Sends Records Requests to FAA, Boeing," Press Release, Committee on Transportation and Infrastructure, U.S. House of Representatives, April 1, 2019, accessed here: https://transportation.house.gov/news/press-releases/as-part-of-investigation-into-boeing-737-max-certification-process-committee-sends-records-requests-to-faa-boeing

[169] In June 2019, DOT/FAA informed the House Committee on Transportation and Infrastructure that, regarding the Committee's investigation of the 737 MAX, it had between 592,915 and 92,265 potentially responsive emails to just a few of the Committee's April 1, 2019, records requests. The FAA acknowledged they had 592,915 emails with the term "MCAS" or "AOA Sensors," for instance, between March 2014 and April 25, 2019. This included 338,074 emails with the terms "MCAS" or "AOA Sensors" and the terms "development" or "testing" or "fielding" or "certification." For the period between March 2014 and October 29, 2018 the number of emails that the FAA identified with the term

Science, and Transportation has experienced remarkably similar problems according to public statements from that Committee's Chairman, Senator Wicker.[170]

- After the Lion Air crash, the FAA's Boeing Aviation Safety Oversight Office (BASOO) started an internal review of its MCAS certification process on the 737 MAX. The review was the first time FAA performed its own detailed analysis of MCAS and the first time FAA received a complete picture of how MCAS operated, according to the Department of Transportation Office of Inspector General (DOT OIG).[171]

- The draft report, titled, "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," concluded that Boeing was compliant with FAA regulations in the certification of the 737 MAX aircraft. "The oversight activity did not reveal any noncompliances," the report said, "but did observe some assumptions used by the Applicant and accepted by the FAA."[172] The report implied that these "assumptions" by both Boeing and the FAA regarding pilot reaction time, for instance, were faulty. The FAA review also found that there was nothing discovered that required "corrective action," although they cited some areas for potential "improvement."[173] The draft report's analysis showed that the MAX was compliant with FAA regulations, raising serious questions about the FAA certification process and its oversight of Boeing.

- This internal FAA review of MCAS began on January 9, 2019,[174] and the last version of the draft report was dated February 8, 2019.[175] The FAA never finalized this report. The FAA told the DOT OIG that the report was going through management review at the time of the Ethiopian Airlines accident and that it was simply overtaken by events.[176]

"MCAS" or "AOA Sensors" was 234,425. In relation to the terms "MCAS" or "AOA Sensors" and the terms "development" or "testing" or "fielding" or "certification," for that same time period, the FAA had identified 92,265 emails. See: "FAA Responses to Follow-Up Questions from House T&I Staff," June 7, 2019, BATES Number FAA-T&I-000192. In addition, in November 2019, in order to help DOT manage the scope of the Committee's requests and at the specific suggestion of DOT, the Committee provided DOT with a list of 13 specific searches of 27 current and former FAA officials. The Committee has received several productions of records related to this request. However, DOT has been unable or unwilling to inform the Committee which of these 13 searches have been performed or which of the 27 individuals' records have been searched.

[170] Prepared Statement, Chairman Roger Wicker, Hearing titled, "Examining the Federal Aviation Administration's Oversight of Aircraft Certification," Senate Committee on Commerce, Science & Transportation, June 17, 2020, accessed here: https://www.commerce.senate.gov/2020/6/examining-the-federal-aviation-administration-s-oversight-of-aircraft-certification

[171] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, p. 32, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[172] "FAA MCAS Oversight Report (draft)." This document was reviewed remotely by Committee staff on May 1, 2020.

[173] Ibid.

[174] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, p. 32, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[175] FAA MCAS Oversight Report (draft), February 8, 2019.

[176] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report

- The metadata of this report showed that the report was accessed and printed by an FAA employee on March 11, 2019, the day after Ethiopian Airlines flight 302 crashed.

- Because this report was a "draft" and a final copy was never produced the DOT refused to provide a copy to the Committee. However, Committee staff were given the opportunity to review the document.

-Investigative Findings Conclusion-

Boeing's design and development of the 737 MAX was marred by technical design failures, lack of transparency with both regulators and customers, and efforts to downplay or disregard concerns about the operation of the aircraft. During development of the 737 MAX, a Boeing engineer raised safety concerns about MCAS being tied to a single AOA sensor.[177] Another Boeing engineer raised concerns about not having a synthetic airspeed system on the 737 MAX.[178] Concerns were also raised about the impact of faulty AOA data on MCAS[179] and repetitive MCAS activations on the ability of 737 MAX pilots to maintain control of the aircraft.[180] Ultimately, all of those safety concerns were either inadequately addressed or simply dismissed by Boeing.

In the wake of the Lion Air and Ethiopian Airlines tragedies, Boeing has now acknowledged some of these issues through its actions. For instance, Boeing now plans to have two AOA sensors feed into MCAS.[181] Boeing has also said that MCAS will no longer activate repeatedly.[182] In January 2020, Boeing dramatically reversed course yet again, by recommending that pilots undergo simulator training on the 737 MAX once the airplane returns to service.[183] That decision violated one of the premier principles of the MAX program, to avoid pilot simulator training. Unfortunately, Boeing's responses to safety issues raised in the 737 MAX program have consistently been too late.

No. AV2020037, June 29, 2020, p. 32, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[177] Boeing employee email, "MCAS Stab Rapid Reversal on PSIM Model," December 17, 2015, BATES Number TBC-T&I 010584 - TBC-T&I 010586 at TBC-T&I 010584, released at Hearing before the House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 121, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[178] Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[179] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOC 2]," Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC T&I 246488 – T&I 246493 at T&I 246489. (On file with Committee) .

[180] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," June 20, 2016, BATES Number TBC T&I 220826 - TBC T&I 220827 at TBC T&I 220826. (On file with the Committee).

[181] "737 MAX Software Update," The Boeing Company, accessed here: https://www.boeing.com/commercial/737max/737-max-software-updates.page

[182] Ibid.

[183] "Boeing Statement on 737 MAX Simulator Training," The Boeing Company, January 7, 2020, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130596 and Natalie Kitroeff and David Gelles, "In Reversal, Boeing Recommends 737 MAX Simulator Training for Pilots," *New York Times,* January 8, 2020, accessed here: https://www.nytimes.com/2020/01/07/business/boeing-737-max-simulator-training.html

The Committee's investigation has also found that the FAA's certification review of Boeing's 737 MAX was grossly insufficient and that the FAA failed in its duty to identify key safety problems and to ensure that they were adequately addressed during the certification process. The combination of these problems doomed the Lion Air and Ethiopian Airlines flights.

The following pages detail the factual evidence gathered by the Committee during its investigation that highlight the actions and events that undermined the design, development, and certification of the 737 MAX aircraft and led to the tragic death of 346 people.

3. Brief Boeing History and 737 MAX Background

-Brief Boeing History and 737 MAX Background-

The Boeing Company was founded more than 100 years ago by William Edward Boeing. Mr. Boeing was born in 1881 in Detroit, Michigan, and attended Yale University prior to leaving in 1903 before graduating to start a lumber company in Washington State.[184] He saw his first airplane in 1909, soon became a pilot, and went into business with U.S. Navy Commander George Conrad Westervelt with the intent of building better airplanes.[185] In 1916, Boeing and Westervelt founded the Pacific Aero Products Company.[186] The company's first airplane, the Boeing Model 1 (B&W Seaplane) flew in June 1916.[187] Less than one year later, soon after the United States entered World War I, the company's name was changed to the Boeing Airplane Company, and it quickly obtained orders from the U.S. Navy to build Navy aircraft trainers.[188] Boeing soon also obtained an airmail route from Chicago to San Francisco that required Boeing to deliver 26 airmail airplanes by July 1, 1927.[189]

William Boeing was known as a stickler for accuracy, facts, and quality. He reportedly kept a placard outside his office quoting from Hippocrates[190] that facts are the foundation of truth and accurate observations.[191] Soon after he established his airplane company in 1916, he noticed improperly cut wooden planks called "spruce ribs" in his airplane factory and walked all over them until they broke, remarking that he would rather close down his shop than send out inferior work of that kind.[192] As his biography states: "He believed in details and told his managers that many a wrong decision stemmed from a detail overlooked or incorrectly interpreted."[193]

The Boeing Company has been a pioneer in aircraft and aviation related technology ever since. In 1928, the company had 1,000 employees.[194] Today it employs more than 150,000 people engaged in producing commercial and military airplanes and spacecraft in more than 150 countries.[195] The company produced the first modern passenger aircraft in 1933, the B-52 Bomber in 1952, the Lunar Rover used to explore the moon in 1971, and large portions of the International

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[184] "Biography of William E. Boeing," The Boeing Company, accessed here: https://www.boeing.com/history/pioneers/william-e-boeing.page
[185] Ibid.
[186] "Pacific Aero Products Company: July 15, 1916," This Day in Aviation, accessed here: https://www.thisdayinaviation.com/tag/pacific-aero-products-company
[187] "Biography of William E. Boeing," The Boeing Company, accessed here: https://www.boeing.com/history/pioneers/william-e-boeing.page
[188] Ibid. (Boeing's name was changed to "The Boeing Company" in 1961. See: Stanley I. Weiss and Amir R. Amir, "The Boeing Company," Encyclopedia Britannica, accessed here: https://www.britannica.com/topic/Boeing-Company)
[189] "Biography of William E. Boeing," The Boeing Company, accessed here: https://www.boeing.com/history/pioneers/william-e-boeing.page
[190] Hippocrates was a Greek physician born in 460 BC who is credited with writing the Hippocratic Oath that pledged to help others and do no harm. The Hippocratic Oath is attributed with being a pillar of modern medical ethics today. See: Wesley D. Smith, "Hippocrates: Greek physician," Encyclopedia Britannica, (last updated) May 18, 2020, accessed here: https://www.britannica.com/biography/Hippocrates and "Greek Medicine: The Hippocratic Oath," History of Medicine Division, National Library of Medicine, National Institutes of Health (NIH), accessed here: https://www.britannica.com/biography/Hippocrates
[191] "Biography of William E. Boeing," The Boeing Company, accessed here: https://www.boeing.com/history/pioneers/william-e-boeing.page
[192] Ibid.
[193] Ibid.
[194] Ibid.
[195] "Boeing in Brief," The Boeing Company, accessed here: https://www.boeing.com/company/general-info/

Space Station (ISS).[196] It has also built some of the world's most well-known modern commercial passenger airplanes, including the 707 that entered commercial service in 1958, followed by the 727 in 1964, the 737 in 1968, the 747 in 1970, and the 767 in 1981, as well as many other aircraft.[197]

Merging Companies – Changing Cultures

In 1997, Boeing merged with McDonnell Douglas[198] and four years later, moved its headquarters from Seattle to Chicago.[199] That merger and the move of Boeing's headquarters has been widely reported to have dramatically shifted the emphasis at Boeing from one devoted to solving difficult engineering problems to one dedicated to enhancing and expanding Boeing's financial profits.[200]

After the merger, Harry Stonecipher, the Chief Executive Officer (CEO) of McDonnell Douglas became the President and Chief Operating Officer of Boeing.[201] In 2004 he told the *Chicago Tribune*: "When people say I changed the culture of Boeing, that was the intent, so it's run like a business rather than a great engineering firm. It is a great engineering firm, but people invest in a company because they want to make money."[202] Those sentiments, according to many observers and current and former Boeing employees, infected the company. They point to that philosophy, which focused on financial benefit rather than technical solutions and innovation, as setting the stage for many of the issues that ultimately contributed to the crashes of the two 737 MAX aircraft.

Harry Stonecipher, former President and Chief Operating Officer of Boeing (as quoted in the *Chicago Tribune*) February 29, 2004

"WHEN PEOPLE SAY I CHANGED THE CULTURE AT BOEING, THAT WAS THE INTENT, SO IT'S RUN LIKE A BUSINESS RATHER THAN A GREAT ENGINEERING FIRM…"

For the past century, Boeing has been a tremendously successful and innovative company, admired for its achievements and singular importance to the U.S. economy. However, critics contend that the company's rising stock value over the past two decades was not directly correlated to any technical success.[203] Some, in fact, have argued that recent fixation within the company on

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[196] Dragan Radovanovic and Benjamin Zhang, "Here are some of the most important moments from Boeing's 100 years of business," *Business Insider,* August 8, 2016, accessed here: https://www.businessinsider.com/boeing-100-years-business-2016-7

[197] Stanley I. Weiss and Amir R. Amir, "The Boeing Company," Encyclopedia Britannica, accessed here: https://www.britannica.com/topic/Boeing-Company

[198] Ibid.

[199] Ibid.

[200] Natasha Frost, "How the McDonnell Douglas-Boeing merger led to the 737 MAX crisis," *Quartz,* January 3, 2020, accessed here: https://qz.com/1776080/how-the-mcdonnell-douglas-boeing-merger-led-to-the-737-max-crisis

[201] "The Boeing Logbook 1997-2001," The Boeing Company, accessed here: https://web.archive.org/web/20130102173045/http://www.boeing.com/history/chronology/chron16.html

[202] Patricia Callahan, "So why does Harry Stonecipher think he can turn around Boeing?" *Chicago Tribune*, February 29, 2004, accessed here: https://www.chicagotribune.com/chi-0402290256feb29-story.html

[203] When Boeing and McDonnell Douglas merged together in August 1997 Boeing's stock was $58 per share. On October 8, 2018, just weeks before the Lion Air crash, Boeing's stock was $383 per share. Despite the crash, Boeing's stock price continued to rise. On March 1, 2019, nine days before the Ethiopian Airlines crash, Boeing's stock price stood at $440 per share. On December 2, 2019, before the COVID-19 (coronavirus) crisis dramatically impacted the aviation industry, Boeing's stock price was $355 per share. Largely due to the fallout of the coronavirus on the entire

Boeing's stock price and financial success undermined the emphasis on technical achievements and innovation. William Lazonick, a Professor in Economics and Co-Director of the Center for Industrial Competitiveness at the University of Massachusetts in Lowell, Massachusetts, has written that Boeing's attempts to profit undermined its efforts to protect the flying public.[204] Lazonick's research highlighted the fact that between 2013 and 2019, during the critical 737 MAX design, development, and certification process, Boeing spent $17.4 billion on stock dividends and an additional $43.1 billion on stock buybacks.[205] Lazonick wrote that these investment strategies may have played key roles in Boeing not spending enough money on issues critical to the safe design and development of the MAX, including adequate testing and safety analyses.[206]

Financial and economic competitiveness also played a key role in Boeing's eventual decision to re-engine an existing airplane rather than design a new airplane in choosing its next product. In 2011, the estimated cost of building a brand-new airplane hovered around $10 billion while the cost of re-engining the existing 737 NG to develop the new 737 MAX airplane was only about $3 billion, according to Richard Aboulafia with the aviation industry market analysis firm, the Teal Group.[207]

Multiple current and former Boeing employees who have contacted the Committee since our investigation began have relayed dismay at the path they believe Boeing has taken since its merger with McDonnell Douglas. They have described their excitement and enthusiasm at joining one of the world's most esteemed companies decades ago. They were thrilled to be working with smart, intelligent, and dedicated colleagues. They viewed Boeing as an engineer's paradise where they could innovate and create leading edge technologies where safety was always at the forefront of engineering decisions that were part and parcel of the business development process.

However, that emphasis changed slowly, but dramatically, over the years, according to these employees. The prowess of the engineers' technical designs and innovative diagrams were replaced by the accounting acumen and financial decisions of business executives. Production schedules and monetary costs, not technical specifications and safety considerations, began to drive Boeing's commercial aircraft programs, they say. These individuals were disturbed, but not surprised, by the tragic consequences that have since been revealed regarding the technical missteps and misguided judgments that impacted the design, development, and certification of Boeing's 737 MAX aircraft.

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aviation industry, on May 1, 2020, Boeing's stock price had dropped to $133 per share. "The Boeing Company," MarketWatch, accessed here: https://www.marketwatch.com/investing/stock/BA/historical

[204] William Lazonick and Mustafa Erdem Sakinc, "Make Passengers Safer? Boeing Just Made Shareholders Richer," *The American Prospect*, May 31, 2019, accessed here: https://prospect.org/environment/make-passengers-safer-boeing-just-made-shareholders-richer

[205] Ibid.

[206] Ibid.

[207] Steve Wilhelm, "What's the ROI for Boeing 737 replacement?," *Puget Sound Business Journal*, July 5, 2011, accessed here: https://www.bizjournals.com/seattle/blog/2011/07/whats-the-roi-for-boeing-737.html

Competitive Pressure

In December 2010, Boeing's chief competitor in the civil airplane market—the European consortium Airbus—launched the A320neo family of aircraft.[208] The term "neo" stood for new engine option and was powered by new fuel-efficient engines that promised up to 15-percent greater fuel efficiency over previous aircraft.[209] This translated into significant cost savings for airlines and potentially passengers, and created a competitive advantage for Airbus. But Boeing initially downplayed this competitive threat.

At a Boeing Commercial Airplanes (BCA) employee meeting on January 14, 2011, James Albaugh, BCA's CEO, said: "I think Airbus will find re-engining the A320 more challenging than they think it will be."[210] He did not think the new Airbus could compete with Boeing's 737 NG aircraft. "At the same time, while we haven't made a firm decision," said Albaugh, "I don't think we will re-engine the 737. It's really hard to come up with a compelling business case to do that," he said. "We think the right answer [is] to probably do a new small airplane that might come out toward the end of this decade." Albaugh added: "Every customer I talk to has a real hard time understanding why a re-engined airplane makes sense."[211] But a call to Albaugh's boss changed that position.

James Albaugh
former Boeing Commercial Airplanes
Chief Executive Officer
January 14, 2011

"EVERY CUSTOMER I TALK TO HAS A REAL HARD TIME UNDERSTANDING WHY A RE-ENGINED AIRPLANE MAKES SENSE."

According to the *New York Times*, in the spring of 2011, the CEO of The Boeing Company, Jim McNerney, received a call from Gerard Arpey, the CEO of American Airlines. The call was reportedly serious and the conversation frank. Boeing was told that American Airlines was about to close a deal to purchase hundreds of A320-family airplanes from Airbus. If Boeing wanted to maintain its business with American Airlines, Boeing would need to step up soon and offer a similar alternative aircraft or lose out on maintaining American as a customer.[212]

The call reportedly rattled Boeing's executives. For more than a decade, American Airlines had exclusively purchased Boeing aircraft.[213] The announcement that the airline planned to purchase aircraft from Airbus was a huge strategic blow to Boeing. The company had been planning to

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[208] "Airbus offers new fuel saving engine options for A320 Family," Airbus, December 1, 2010, accessed here: https://www.airbus.com/newsroom/press-releases/en/2010/12/airbus-offers-new-fuel-saving-engine-options-for-a320-family.html
[209] Ibid.
[210] "Boeing didn't want to re-engine the 737–but had design standing by," *Leeham News and Analysis*, March 20, 2019, accessed here: https://leehamnews.com/2019/03/20/boeing-didnt-want-to-re-engine-the-737-but-had-design-standing-by
[211] Ibid.
[212] David Gelles, Natalie Kitroeff, Jack Nicas and Rebecca R. Ruiz, "Boeing Was 'Go, Go, Go' to Beat Airbus With the 737 Max," *New York Times*, March 23, 2019, accessed here: https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html
[213] Ibid.

develop a completely new airplane.[214] Since 2005, Boeing had been toying with the idea of developing a brand-new "clean sheet" commercial airplane. Boeing dubbed these efforts to design a new commercial aircraft to replace the 737 NG "Project Yellowstone."[215]

However, the phone call between the two CEOs at American Airlines and Boeing changed all that. Rather than endeavoring to develop a "clean sheet" airplane that would apply the lessons learned from Boeing's other commercial aircraft, including the 737, Boeing instead decided to remodel its existing 737 NG aircraft so the company would not have to start from scratch, saving time, resources, and costs in the process.

On July 20, 2011, Airbus announced that American Airlines had placed an order for 260 A320 family aircraft, including 130 of its new A320neo aircraft.[216] But given Boeing's reversal and commitment to re-engining the 737 NG, American Airlines also pledged to purchase 100 737-800s and 100 737 MAX airplanes.[217] The airline said it was "pleased to be the first airline to commit to Boeing's new 737 family offering, which [was] expected to provide a new level of economic efficiency and operational performance, pending final confirmation of the program by Boeing."[218]

Boeing Press Release
August 30, 2011

"THE RE-ENGINED 737 WILL ALLOW BOEING TO CONTINUE TO DELIVER THE MOST FUEL EFFICIENT, MOST CAPABLE AIRPLANE WITH THE LOWEST OPERATING COSTS IN THE SINGLE-AISLE MARKET."

The following month, Boeing announced its intent to develop a new commercial aircraft. In stark contrast to what Albaugh told Boeing's employees just seven months earlier, Boeing issued an August 2011 press release that quoted Albaugh as saying: "The re-engined 737 will allow Boeing to continue to deliver the most fuel efficient, most capable airplane with the lowest operating costs in the single-aisle market."[219] The press release noted that Boeing had already secured commitments from five customers for 496 of the new airplanes.[220] Ignoring the statements that Albaugh had made to Boeing employees earlier in the year, the press release asserted: "Customers expressing overwhelming acceptance for new airplane."[221]

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[214] "Boeing didn't want to re-engine the 737–but had design standing by," *Leeham News and Analysis*, March 20, 2019, accessed here: https://leehamnews.com/2019/03/20/boeing-didnt-want-to-re-engine-the-737-but-had-design-standing-by
[215] "Countdown to Launch: The Boeing 737 MAX Timeline," *Airways*, January 27, 2016, accessed here: https://airwaysmag.com/industry/boeing-737-max-timeline
[216] "American Airlines acquires 260 Airbus A320 Family aircraft," Airbus, July 20, 2011, accessed here: https://www.airbus.com/newsroom/press-releases/en/2011/07/american-airlines-acquires-260-airbus-a320-family-aircraft.html
[217] Ibid.
[218] "AMR Corporation Announces Largest Aircraft Order in History with Boeing and Airbus," Press Release, American Airlines, July 20, 2011, accessed here: https://www.sec.gov/Archives/edgar/data/4515/000119312511191876/dex992.htm
[219] "Boeing Launches 737 New Engine Family with Commitments for 496 Airplanes from Five Airlines," Press Release, The Boeing Company, August 30, 2011, accessed here: https://boeing.mediaroom.com/2011-08-30-Boeing-Launches-737-New-Engine-Family-with-Commitments-for-496-Airplanes-from-Five-Airlines
[220] Ibid.
[221] Ibid.

3. Brief Boeing History and 737 MAX Background

Boeing's 737 aircraft had been a dependable and successful aircraft since its development five decades earlier. For Boeing, it was hard to let go of a good thing and gamble on developing a brand-new aircraft. At the time of Boeing's announcement to develop the new 737 MAX, Boeing had delivered more than 9,000 of the 737 aircraft, in their various derivative models, since the first 737 had come off Boeing's assembly line in 1967.[222] Producing a brand new aircraft would have been technically exciting and challenging, but the costs and time involved in doing so made Boeing's executives anxious that they would lose out in competition to Airbus. Even once a decision was made to update the 737, then known as the 737 NG (Next Generation), and replace it with the new 737 MAX aircraft, an aggressive production schedule and cost-conscious measures aimed at competing with Airbus played a paramount role in the program.

Schedule and production pressures impacted the 737 MAX program throughout its design and certification process. But these pressures were not unique to the MAX program. Boeing's other primary commercial aircraft program, the 787 Dreamliner, was reportedly losing tens of millions of dollars on each 787 it built. In June 2015, a *Forbes* magazine contributor wrote: "These recurring production losses (on top of 787 development costs) stood at over $26 billion in January and will likely reach $30 billion, and possibly beyond."[223] Boeing needed a competitive profit-making commercial aircraft, and the company believed the 737 MAX was the answer.

Further, design issues that affected safety of the 787 Dreamliner foreshadowed eventual problems that emerged in the 737 MAX program. In January 2013, the newly certified 787 was grounded globally after two auxiliary power lithium ion battery fire incidents.[224] In November 2014, after an almost two-year investigation, the National Transportation Safety Board (NTSB) released its results and identified numerous issues in the design and certification of the 787 Dreamliner's new lithium batteries.[225] The report identified issues that, in many cases, parallel the findings of the Committee's investigation of the 737 MAX. Among its findings, NTSB found inadequate FAA oversight, a failure by both FAA and Boeing's Authorized Representatives (ARs) to identify critical deficiencies, and flawed safety assumptions by Boeing that it made into the airplane's System Safety Assessment.[226] One year before the 787's grounding, Boeing's efforts to develop the 737 MAX were already underway.

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[222] See: "Boeing Launches 737 New Engine Family with Commitments for 496 Airplanes from Five Airlines," Press Release, The Boeing Company, August 30, 2011, accessed here: https://boeing.mediaroom.com/2011-08-30-Boeing-Launches-737-New-Engine-Family-with-Commitments-for-496-Airplanes-from-Five-Airlines and Natasha Frost, "How the McDonnell Douglas-Boeing merger led to the 737 MAX crisis," *Quartz*, January 3, 2020, accessed here: https://qz.com/1776080/how-the-mcdonnell-douglas-boeing-merger-led-to-the-737-max-crisis

[223] Richard Aboulafia, "Boeing Will Pay High Price For McNerney's Mistake Of Treating Aviation Like It Was Any Other Industry," *Forbes*, June 24, 2015, accessed here: https://www.forbes.com/sites/richardaboulafia/2015/06/24/boeing-mcnerney-and-the-high-price-of-treating-aircraft-like-it-was-any-other-industry/#3a2aec3b579c

[224] Jad Mouawad, "Report on Boeing 737 Dreamliner Battery Flaws Finds Lapses at Multiple Points," *New York Times*, December 1, 2014, accessed here: https://www.nytimes.com/2014/12/02/business/report-on-boeing-787-dreamliner-batteries-assigns-some-blame-for-flaws.html

[225] "Aviation Incident Report: Auxiliary Power Unit Battery Fire Japan Airlines Boeing 787-8, JA829J, Boston Massachusetts," January 7, 2013, NTSB/AIR-14/01, National Transportation Safety Board (NTSB), November 21, 2014, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/AIR1401.pdf

[226] Ibid.

From Marketing Marvel to Financial Burden

On January 27, 2012, Boeing initially submitted its proposal for an Amended Type Certificate to develop the 737 MAX aircraft to the FAA.[227] The 737 MAX ultimately became Boeing's fastest-selling airplane ever produced.[228] When the 737 MAX was granted its Amended Type Certificate from the FAA on March 9, 2017,[229] Boeing had already acquired more than 3,600 orders for the 737 MAX airplane from 83 customers worldwide.[230] The following month the company obtained orders for 42 more aircraft from airlines in Mongolia, Iran, and Azerbaijan.[231] At the time of its certification, Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, said: "This certification is a true testament to the dedication and commitment of our entire MAX team throughout the process, from airplane design to flight testing."[232]

Boeing was making substantial profit on each 737 MAX it delivered prior to the Lion Air and Ethiopian Airlines crashes. Moody's credit-rating agency estimated that Boeing was making on average between $12 and $15 million on each 737 MAX it delivered.[233] But the two MAX crashes have taken a tremendous financial toll on the company costing Boeing nearly $19 billion so far, and problems on the MAX have continued to mount as more issues have been discovered since the aircraft was grounded.[234]

Southwest Airlines, the U.S. launch customer for the 737 MAX, was reportedly losing $67,000 per day, per airplane since the 737 MAX groundings in the days after the Ethiopian Airlines crash (prior to the COVID-19 impact on the airline industry).[235] Southwest had 34 737 MAX aircraft in its fleet when the MAX was grounded.[236] American Airlines was also losing an estimated $50,000

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[227] G-1 Issue Paper, Project: Boeing Commercial Airplanes, Model 737-8, Project No. PS12-0038, June 30, 2012, BATES Number FAA-DeFazio 200-277. (Hereafter referred to as "G-1 Issue Paper.") (On file with the Committee).
[228] "Boeing, Malindo Air Celebrate First 737 MAX Delivery," Press Release, Boeing Commercial Airplanes, May 16, 2017, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=129894
[229] "Boeing 737 MAX 8 Earns FAA Certification," Press Release, The Boeing Company, March 9, 2017, accessed here: https://boeing.mediaroom.com/2017-03-09-Boeing-737-MAX-8-Earns-FAA-Certification
[230] Ibid.
[231] See: "Boeing 737 MAX to Join MIAT Mongolian Airlines Fleet," Press Release, Boeing Commercial Airplanes, April 3, 2017, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=129875 and "Boeing Announces Agreement with Iran Aseman Airlines for 30 737 MAXs," Press Release, Boeing Commercial Airplanes, April 4, 2017, accessed here: https://boeing.mediaroom.com/2017-03-17-Boeing-Announces-Agreement-with-Iran-Aseman-Airlines-for-30-737-MAXs; and "Boeing, Silk Way Announce Order for Ten 737 MAX 8 airplanes," Press Release, Boeing Commercial Airplanes, April 14, 2017, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=129883
[232] Ibid.
[233] Benjamin Zhang, "Here's how much Boeing is estimated to make on each 737 MAX 8 plane," *Business Insider,* March 13, 2019, accessed here: https://www.businessinsider.in/heres-how-much-boeing-is-estimated-to-make-on-each-737-max-8-plane/articleshow/68399220.cms
[234] Dominic Rushe, "Boeing puts cost of 737 Max crashes at $19bn as it slumps to annual loss," *The Guardian*, January 29, 2020, accessed here: https://www.theguardian.com/business/2020/jan/29/boeing-puts-cost-of-737-max-crashes-at-19bn-as-it-slumps-to-annual-loss
[235] Darryl Campbell, "The 737 Built Southwest, and the 737 MAX Could Be its Undoing," *The Verge*, October 23, 2019, accessed here: https://www.theverge.com/2019/10/23/20927213/boeing-737-max-southwest-planes-crash-budget-airlines-grounded-cost-maintenance
[236] David Slotnick and *Reuters*, "Boeing is compensating Southwest for the 737 Max grounding, and the airline is sharing $125 million of the agreed total with employees," *Business Insider*, December 12, 2019, accessed here: https://www.businessinsider.com/southwest-airlines-reaches-compensation-agreement-with-boeing-2019-12

per day, per airplane[237] following the grounding and had 24 MAX aircraft in its fleet at the time of the grounding.[238]

Certifying the 737 MAX

The 737 MAX is the 12th derivative aircraft of the 737 since it received its original FAA certification in December 1967.[239] Over its lifespan, 737 derivatives have been classified into three major categories, the 737 Classic, the 737 NG (Next Generation) and the 737 MAX.[240] Each new category of aircraft included a new engine, improved range, greater fuel efficiency, and less noise.[241]

There were significant modifications to the 737 MAX version compared to the 737 NG.[242] Most dramatically and significantly, this included the addition of new larger CFM LEAP-1B engines. Since the engines on 737s sit below the wings, and the 737 sits relatively low to the ground, the larger engines had to be mounted further forward and higher up on the wings in order to maintain sufficient ground clearance.[243] To prevent the larger engines from dragging on the ground, the 737 MAX's nose gear was extended by about 8 inches.[244] Additionally, when compared to the 737 NG, its weight increased by more than 6,500 pounds, the tail cone was extended by 43 inches, and its flight deck was modernized.[245] Importantly, these changes altered the aerodynamics of the aircraft,

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[237] Darryl Campbell, "The 737 Built Southwest, and the 737 MAX Could Be its Undoing," *The Verge*, October 23, 2019, accessed here: https://www.theverge.com/2019/10/23/20927213/boeing-737-max-southwest-planes-crash-budget-airlines-grounded-cost-maintenance

[238] David Slotnick and *Reuters*, "Boeing is compensating Southwest for the 737 Max grounding, and the airline is sharing $125 million of the agreed total with employees," *Business Insider*, December 12, 2019, accessed here: https://www.businessinsider.com/southwest-airlines-reaches-compensation-agreement-with-boeing-2019-12

[239] The 737 MAX was the 12th "derivative" of the original 737-100 aircraft certified in 1967, making it the 13th 737 model aircraft produced by Boeing. See: "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf.

[240] While there are three major categories of 737 derivative aircraft (the 737 Classic, 737 NG and 737 MAX), the Boeing 737 MAX series is the fourth-generation model of Boeing's 737 aircraft. These four generations include the 737-100, 737 Classic, 737 NG and 737 MAX. See: "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, p. 5, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[241] "Official Report of the Special Committee to review the Federal Aviation Administration's Aircraft Certification Process," Department of Transportation, January 16, 2020, (Hereafter referred to as the DOT Special Committee report), p. 5, accessed here: https://www.transportation.gov/sites/dot.gov/files/2020-01/scc-final-report.pdf.

[242] Chris Brady, "Boeing 737 MAX – Differences," The Boeing 737 Technical Guide, Updated April 19, 2019, accessed here: http://www.b737.org.uk/737maxdiffs.htm

[243] Ralph Vartabedian, "How a 50-year-old design came back to haunt Boeing with its troubled 737 Max jet," *Los Angeles Times,* March 15, 2019, accessed here: https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html

[244] Ibid.

[245] Chris Brady, "Boeing 737 MAX – Differences," The Boeing 737 Technical Guide, Updated April 19, 2019, accessed here: http://www.b737.org.uk/737maxdiffs.htm

making it more likely to pitch upward[246] during certain flight conditions, putting it at risk of entering a potentially dangerous stall.[247]

However, one of the most significant changes to the aircraft could not be seen. This included the changes to the flight control software that incorporated the addition of the Maneuvering Characteristics Augmentation System (MCAS) to help counter the tendency of the aircraft to pitch up. This addition would prove fatal as the installation of MCAS on the aircraft played a critical role in the two 737 MAX crashes.

Changed Product Rule

On June 30, 2012, Boeing submitted its G-1 Issue Paper to the FAA's Boeing Aviation Safety Oversight Office (BASOO)—the central FAA office designated to oversee Boeing's designee authority and the certification process of the company's aircraft—that highlighted the differences between the 737-800 NG and Boeing's proposed 737-8 MAX aircraft.[248] The G-1 Issue Paper was used to form the "certification basis" for the 737 MAX and "to record issues and resolution for changes to the certification basis."[249]

In all, the issue paper listed 201 distinct "significant changes" between the two aircraft.[250] This included 56 airframe changes, 94 system changes (including 15 avionics changes and 13 flight control changes), 36 propulsion changes, and 15 payload related changes.[251] The G-1 Issue Paper briefly cited MCAS as one of the software changes that resulted in modifications to the Enhanced Digital Flight Control System (EDFCS).[252]

As part of the FAA's certification process, aircraft must comply with procedures detailed in 14 CFR part 21 ("Certification Procedures for Products and Articles"). Within these FAA regulations is the "Changed Product Rule,"[253] which may apply when an applicant seeks certification of a previously approved design to which the applicant is making changes. Changes can be made through an amended type certificate (ATC), a supplemental type certificate (STC), or an amended

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[246] Ralph Vartabedian, "How a 50-year-old design came back to haunt Boeing with its troubled 737 Max jet," *Los Angeles Times,* March 15, 2019, accessed here: https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html

[247] Peter Cohan, "MIT Expert Highlights 'Divergent Condition' Caused By 737 MAX Engine Placement," *Forbes,* April 2, 2019, accessed here: https://www.forbes.com/sites/petercohan/2019/04/02/mit-expert-highlights-divergent-condition-caused-by-737-max-engine-placement/#7c4f24d040aa; see Andy Pazstor, Andrew Tangel, and Alison Sider, "Between two deadly crashes Boeing moved haltingly to make 737 MAX fixes," *Wall Street Journal,* April 1, 2019, accessed here: https://www.wsj.com/articles/between-two-deadly-crashes-boeing-moved-haltingly-to-make-737-max-fixes-11554164171?mod=hp_lead_pos1

[248] G-1 Issue Paper.

[249] "How to Establish the Certification Basis for Changed Aeronautical Products," FAA ORDER 8110.48, Federal Aviation Administration (FAA), April 25, 2013, p. 5, accessed here: https://www.faa.gov/documentLibrary/media/Order/ORDER_8110_48.pdf

[250] G-1 Issue Paper.

[251] G-1 Issue Paper.

[252] G-1 Issue Paper.

[253] 14 CFR § 21.101 – "Designation of applicable regulations," Code of Federal Regulations (CFR), as published in the Federal Register, January 21, 2011, accessed here: https://www.govinfo.gov/app/details/CFR-2011-title14-vol1/CFR-2011-title14-vol1-sec21-101 (The rule was originally issued in 2000 and has been amended several times since then.)

STC.[254] The "Changed Product Rule" process determines whether previous FAA regulatory amendments, rather than the newest or latest amendments, may be applied in certifying an applicant's changed product.[255] Applicants for amended type certificates for derivative airplanes that are versions of already-certificated airplanes must show that the change or any areas affected by the change comply with all applicable FAA airworthiness requirements.[256] There were significant changes to the 737 MAX compared to the 737 NG aircraft.

FAA's G-1 Issue Paper on the 737 MAX, FAA Position on July 21, 2012

"'[T]HE FAA HAS FOUND THAT THE PROPOSED MODEL 737-8 [MAX AIRCRAFT] IS A SIGNIFICANT PRODUCT LEVEL CHANGE."

In 2012, the FAA raised numerous certification-related matters surrounding the 737 MAX. On July 21, 2012, for instance, the FAA declared: "[T]he FAA has found that the proposed Model 737-8 is a significant product level change. Thus, the changed product must comply with the regulations in effect on the date of application for the change unless an exception given in § 21.101(b) applies," the FAA wrote.[257] The applicant, however, may propose exceptions under these regulations if the area is not affected, the change does not contribute materially to the level of safety, and/or if the changes are impractical.[258] "When the applicant proposes exceptions, the FAA engineer must review data submitted and make a finding," according to the FAA.[259]

The Joint Authorities Technical Review (JATR) panel, established by the FAA's Associate Administrator for Aviation Safety in June 2019 as a direct result of the MAX crashes, and comprised of technical representatives from the FAA, National Aeronautics and Space Administration (NASA), and civil aviation authorities from Australia, Brazil, Canada, China, Europe, Indonesia, Japan, Singapore, and the United Arab Emirates, issued its final report in October 2019.[260] As part of its review, the JATR panel evaluated how the Changed Product Rule was applied to the certification of the MAX's flight control system:

> The JATR team determined that the Changed Product Rule process was followed and that the process was effective for addressing discrete changes. However, the team determined that the process did not adequately address cumulative effects, system integration, and human factors issues. The Changed Product Rule process allows the applicant to only address in a limited way changed aspects (and areas affected by

[254] "Joint Authorities Technical Review (JATR) - Boeing 737 MAX Flight Control System: Observations, Findings, and Recommendations" Submitted to the Associate Administrator for Aviation Safety, U.S. Federal Aviation Administration (FAA), October 11, 2019, (Hereafter referred to as "JATR Report"), p. III, accessed here: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf
[255] Ibid.
[256] Ibid.
[257] See: G-1 Issue Paper, p. 20 [FAA Position: July 21, 2012].
[258] "How to Establish the Certification Basis for Changed Aeronautical Products," FAA ORDER 8110.48, Federal Aviation Administration (FAA), April 25, 2013, p. 3, accessed here: https://www.faa.gov/documentLibrary/media/Order/ORDER_8110_48.pdf
[259] Ibid. at p. 5.
[260] JATR Report.

> the change) and does not require analysis of all interactions at the aircraft level.[261]
>
> The current Changed Product Rule process lacks an adequate assessment of how proposed design changes integrate with existing systems and the associated impact of this interaction at the aircraft level. A more fulsome assessment process would apply to establishing the certification basis as well as to finding compliance throughout the certification process.[262]

Since the MAX accidents, however, the FAA has attempted to downplay the differences between the 737 MAX and the 737 NG aircraft. The FAA's web-page on "Airworthiness Certification," that was last modified in December 2019, claimed, for instance, "The Boeing 737-8/9 Max design had minor changes to the 737 Next Generation (NG) design.[263] For this reason, the FAA issued an Amended Type Certificate to the Max airplane, which was based on the Type Certificate of the 737NG."[264] Yet, the JATR pointed out that changes made under the Changed Product Rule could have cumulative effects and impact system integration and human factors.[265]

FAA's G-1 Issue Paper on the 737 MAX, FAA Position on July 21, 2012

"BOEING STATED THAT A MAJOR REASON FOR NOT STEPPING UP TO THE LATEST AMENDMENT IS TO MINIMIZE THE IMPACT OF CHANGES IN THE FLIGHT DECK AND MAINTAIN A COMMON FLIGHT DECK PHILOSOPHY WITH THE 737 FLEET OF AIRPLANES."

Exceptions to the Rule

In order to comply with the FAA certification requirements and to preserve commonality between the 737 MAX and the prior model 737 NG airplane, Boeing applied for several exceptions from FAA design regulations promulgated after the original 737 type certificate was issued in 1967.[266]

On February 6, 2014, the FAA cited one issue -related to this topic. "Within the Boeing proposed exceptions, there may be differences of opinion between the FAA and Boeing with regards to the supporting rationale," the FAA declared.[267] "For example, Boeing stated that a major reason for not stepping up to the latest amendment is to minimize the impact of changes in the

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[261] JATR Report, p. IV.
[262] JATR Report, p. IV.
[263] "Airworthiness Certification," Federal Aviation Administration (FAA), accessed here: https://www.faa.gov/aircraft/air_cert/airworthiness_certification
[264] Ibid.
[265] JATR Report, p. IV.
[266] "Dominic Gates, Steve Miletich and Lewis Kamb, "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," *Seattle Times*, October 2, 2019 (Updated: October 3, 2019), accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts
[267] See G-1 Issue Paper, p. 26 [FAA Position: (February 6, 2014)].

flight deck and maintain a common flight deck philosophy with the 737 fleet of airplanes. Boeing also asserted that updating the 737-8 with an engine-indicating and crew alerting system [EICAS] type system will have a major impact on the type rating and training difference level between the 737-8 and the rest of the 737NG family."[268]

Engine Indicating and Crew Alerting System (EICAS)

Boeing obtained an FAA exception to allow the company to **not** install an Engine Indicating and Crew Alerting System (EICAS) on the 737 MAX.[269] Since 1982, an EICAS or its equivalent among Airbus airplanes has been common in newly certificated transport aircraft. It displays aircraft system faults and failures in the cockpit and helps pilots prioritize responding to multiple or simultaneous indications and alerts, which are often accompanied by aural alerts specific to the level of severity of a particular fault.[270] But the exception from FAA relieved Boeing of the requirement that the 737 MAX must be equipped with a caution, alert, and advisory system that "[p]rovide[s] timely attention-getting cues through at least two different senses by a combination of aural, visual, or tactile indications" and that "[p]revent[s] the presentation of an alert that is inappropriate or unnecessary."[271] Instead, the 737 MAX largely uses legacy cautions, warnings, alerts, and advisories from the previous generation of the 737 aircraft.[272]

"737 MAX Certification Basis Risk Review - EICAS"
The Boeing Company
June 14, 2012

"IF WE HAD TO COMPLY OUTRIGHT WITH REGULATION: CONSIDERABLE PROGRAM COST AND SCHEDULE RISK [AND] SIGNIFICANT [PILOT TRAINING] IMPACT TO OPERATORS WITH A FAMILY OF 737S."

Boeing was well aware early on of the risk posed to the 737 MAX program if it was required to implement an EICAS on the MAX. In June 2012, a Boeing employee gave a presentation titled: "737 MAX Certification Basis Risk Review: EICAS."[273] The presentation defined the issue this way: "Numerous crew alerts on the 737Max are new or revised and per changed product regulation are required to meet latest amendment level. Current 737 flight crew alerting methods won't comply with latest regulation."[274] The presentation went on to say that a "compliant design would be similar to the 787 or 767 tanker and include" EICAS as well as other features.[275] Significantly, the

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[268] Ibid.
[269] Ibid.
[270] Ibid.
[271] See: 14 CFR § 25.1322 – "Flightcrew alerting," Code of Federal Regulations, as published in the Federal Register, January 1, 2016, accessed here: https://www.govinfo.gov/app/details/CFR-2016-title14-vol1/CFR-2016-title14-vol1-sec25-1322 and Dominic Gates, "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts
[272] Chris Brady, ""The 737-MAX Flightdeck," The Boeing 737 Technical Guide, Updated April 19, 2019, accessed here: http://www.b737.org.uk/flightdeck737max.htm
[273] "737 MAX Certification Basis Risk Review: EICAS," The Boeing Company, June 14, 2012, BATES Number TBC T&I 014213-014230 at TBC-T&I 014215 - 014230. (On file with the Committee).
[274] Ibid. at TBC-T&I 014216.
[275] Ibid. at TBC-T&I 014216.

presentation noted: "IF we had to comply outright with regulation: Considerable program cost and schedule risk," it asserted, and "significant impact" on pilot training requirements.[276]

The presentation also specifically cited the FAA's regulation regarding flightcrew alerting requirements (14 CFR § 25.1322). "Current 737 method of alerting will not comply with latest amendment level of [section] 25.1322," one of the slides noted, and it warned that the FAA and the European Union Aviation Safety Agency (EASA) "may not agree with our proposal to get an exception from the latest amendment."[277] But it also noted, "Based on recent program experience, we might be successful convincing the regulators to accept an exception to latest amendment level of 25.1322."[278]

The presentation laid out a plan to do just that. "Change Product Rule allows for an 'exception' to meeting the latest regulations," the presentation said. "Boeing's exception proposal will be based on compliance with the regulation being "impractical."[279] The "cost of complying not commensurate with degree of safety improvement," the presentation suggested.[280]

The presentation also cited "elements of [the] cost story" and said: "Also depends on convincing the FAA that the safety improvement of complying with the new rule is not overwhelming."[281] The presentation said the MAX program would need "help" from Boeing "finance" personnel regarding "how to structure our cost story," and it said that they needed "buy-in to [such an] exception proposal" from Boeing's Authorized Representatives (ARs), who are supposed to represent the interests of the FAA.[282] The presentation ended with the following warning if the 737 MAX was driven to include EICAS in the aircraft – "This would have cascading effects on flight deck design and other systems.".[283]

In the end, the FAA accepted Boeing's argument about the impracticality and the economic expense of installing EICAS on the 737 MAX.[284] This meant that the 737 aircraft family, including the 737 MAX, would continue to be the only presently available Boeing commercial aircraft line that did not have an EICAS installed.[285] Unfortunately, had the EICAS been installed on the Lion Air or Ethiopian Airlines flights, some experts believe it may have helped to alleviate pilot confusion—a contributing factor in both of those accidents.[286]

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[276] Ibid. at TBC-T&I 014216.
[277] Ibid. at TBC-T&I 014228.
[278] Ibid. at TBC-T&I 014228.
[279] Ibid. at TBC-T&I 014223.
[280] Ibid. at TBC-T&I 014223.
[281] Ibid. at TBC-T&I 014223.
[282] Ibid. at TBC-T&I 014225.
[283] Ibid. at TBC-T&I 014228.
[284] Dominic Gates, "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts
[285] Ibid.
[286] "Boeing pushed FAA to relax 737 MAX certification requirements for crew alerts," Dominic Gates, Steve Miletich and Lewis Kamb, *Seattle Times*, October 2, 2019 (Updated: October 3, 2019), accessed here, https://www.seattletimes.com/business/boeing-aerospace/boeing-pushed-faa-to-arelax-737-max-certification-requirements-for-crew-alerts

Human Factors

The National Transportation Safety Board (NTSB) emphasized the need for warning systems like EICAS in a report it issued in response to the Lion Air and Ethiopian Airlines crashes in September 2019, writing:

> Multiple alerts and indications in the cockpit can increase pilots' workload and can also make it more difficult to identify which procedure the pilots should conduct. …
>
> Human factors research has identified that, for non-normal conditions, such as those involving a system failure with multiple alerts, where there may be multiple flight crew actions required, providing pilots with understanding as to which actions must take priority is a critical need.[287]

In addition, the NTSB has also pointed out that critical human factors considerations were lacking during the certification of the 737 MAX but did not specifically distinguish between the different types of certification processes.[288] According to its September 2019 report:

> The NTSB notes that a number of human performance research studies have been conducted in the years since the certification guidance contained in AC 25.1309-1A was put in place (in 1988) …. [I]t is likely that more rigorous, validated methodologies exist today to assess error tolerance with regard to pilot recognition and response to failure conditions. The NTSB also believes that the use of validated methods and tools to assess pilot performance in dealing with failure conditions and emergencies would result in more effective requirements for flight deck interface design, pilot procedures, and training strategies. However, we are concerned that such tools and methods are still not commonplace or required as part of the design certification process for functions such as MCAS on newly certified type designs.[289]

A Holistic Review Process?

Both the JATR and the NTSB analyses found room for substantial improvement in how commercial transport aircraft are certified. Even the Special Committee, established by the Secretary of Transportation to review the FAA's certification process following the MAX crashes, which took a somewhat different view regarding the thoroughness of the amended type certification (ATC) process, conceded there is opportunity for improvement regarding this certification process on "assumptions related to pilot performance and training, clarification and implementation of human

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[287] "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, (Hereafter referred to as "NTSB Safety Recommendation Report"), pp. 10-11, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf

[288] Ibid., p. 9.

[289] Ibid.

factors assessments, review of the cumulative effect of multiple changes to aircraft design, providing of a holistic system operational risk assessment, and internal communication and communication between Boeing and FAA." [290]

While some have questioned whether the use of an ATC process is problematic and not as thorough as a new Type Certificate (TC) process, the Special Committee took a different view. "In nearly all its interviews, the Committee asked a wide range of stakeholders the same two questions," the report said. "'If Boeing had applied for a new type certificate for the 737 MAX 8, would it have made a difference to the level of scrutiny of the aircraft during certification?' and 'Would seeking certification via a new TC [Type Certificate] have produced a safer aircraft?' The answer from the experts was consistent; each said a new TC would not have produced more rigorous scrutiny of the 737 MAX 8 and would not have produced a safer airplane," the Special Committee wrote.[291]

That conclusion appears to be at odds with the position of some aviation experts. One current Boeing aerospace engineer, who worked on the 737 MAX, wrote to the Senate Committee on Commerce, Science, and Transportation in June 2020 regarding his observations about safety concerns on the MAX and the certification process that permitted the MAX to be certified by the FAA. He specifically cited the DOT Special Committee's claim that a new type certification would not have produced a "safer airplane." "This conclusion is utterly incorrect," he wrote. Because the MAX was certified under an "Amended Type Certification," it was not required to meet many of the safety regulations that had emerged since the plane's original certification back in 1967 and therefore avoided installing some modern safety features on the airplane, such as various crew alerting systems.[292] He also alleged that the MAX's certification "was accomplished with hand-waving and deception to hide the numerous ways the 1960s-era design of the 737 does not meet current regulatory standards or a modern concept of aviation safety" and that going through the ATC process "severely limited the range of human factors evaluation of 737 MAX systems."[293]

Separately, Professor Ronnie Gipson, an aviation attorney at the Cecil C. Humphreys School of Law at the University of Memphis, recently wrote about the MAX crashes. "It is clear that there needs to be a change in the way amended type certificates for design changes are approved.[294] The current process is a remnant of the FAA's bipartite mandate by Congress to promote air travel," he wrote.[295] Professor Gipson focused on flight testing issues, "but the lesson learned from the 737MAX debacle for the aviation industry and the FAA," he argued, "is that the current certification system for changes to aircraft design is inadequate."[296]

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[290] DOT Special Committee, p.8, accessed here: https://www.transportation.gov/sites/dot.gov/files/2020-01/scc-final-report.pdf
[291] Ibid.
[292] See: Dominic Gates, "Boeing whistleblower alleges systemic problems with 737 MAX," *Seattle Times*, June 18, 2020, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblower-alleges-systemic-problems-with-737-max and Letter to U.S. Senate Committee on Commerce, Science, and Transportation from Boeing employee, June 5, 2020. (On file with the Committee).
[293] Ibid.
[294] Ronnie R. Gipson, Jr., "The FAA's Aircraft Design Approval Process Must be Overhauled," *Empire Bar Review*, Issue 20, Federal Bar Association, Spring 2019, p. 11, accessed here: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3373387
[295] Ibid.
[296] Ibid.

In addition, despite the responses the DOT Special Committee received suggesting that there were no fundamental differences regarding safety in an ATC review or a new TC review, it appeared to acknowledge that a much broader holistic review was necessary in order to identify potential safety issues, particularly regarding human factors. "However, the [DOT Special] Committee concluded that additional consideration of the interface between the changed item and the rest of the [airplane] system, as well and the impact of multiple changes over time, should be required," they wrote.[297] "This includes assessment of their combined effect on the flight crew's ability to safely manage operational tasks."[298]

The FAA's JATR, which focused on the MAX's flight control system, also observed: "There are no criteria for determining when the core attributes of an existing design make it fundamentally incapable of supporting the safety advancements introduced by the latest amendments to airworthiness standards."[299] Furthermore, the report found: "The requirements of an amended type certificate certification process to focus only on "change and areas affected by the change" may fail to recognize that the whole aircraft system (including the flight crew) could be affected by seemingly small changes."[300]

While certification guidance does not incorporate the more rigorous methodologies that have been developed since FAA Advisory Circular 25.1309-1A on "System Design and Analysis" was issued in 1988, it is reasonable to think that certifying the 737 MAX as a new aircraft, rather than a 737-derivative model, under the ATC process, may have helped to identify the potential safety implications of new technologies that were incorporated into the 737 MAX. This would have allowed for a more holistic assessment of all of the functions of all of the plane's systems.

In contrast, certifying the 737 MAX as a derivative model led Boeing's engineers and managers to think about how to minimize the impact of new features, such as MCAS, on older, established technologies that had already been certified on previous 737 aircraft. As a result, designers thought narrowly about MCAS as a discrete addition. This also limited their evaluation of how MCAS would function along with, or at the same time as, other, seemingly unrelated systems. Efforts to access the potential cascading effects MCAS could have on these other systems and on the pilots' ability to control the aircraft as a result of an MCAS malfunction or design flaw were not evaluated thoroughly enough.[301] Not adequately assessing the unintended consequences of new technologies, or new functions or applications of existing technologies, on older components of the 737 MAX led to missed opportunities to identify potential safety risks to the aircraft, passengers, and crew.

Trouble from the Start

Despite the promise of a technically improved, energy efficient, and financially competitive aircraft that could compete with the Airbus A320neo aircraft, there was trouble on the 737 MAX from the very start. Boeing's 737 MAX aircraft had technical and operational issues that should have

[297] DOT Special Committee, p.7, accessed here: https://www.transportation.gov/sites/dot.gov/files/2020-01/scc-final-report.pdf
[298] Ibid..
[299] JATR Report, p. 7.
[300] Ibid., p. 10.
[301] See JATR, p. IV, recommending Change Product Rules and associated guidance be revised, "to require a top-down approach whereby every change is evaluated from an integrated whole aircraft system perspective."

served as an early warning sign of bigger troubles yet to come. In March 2016, during one of the aircraft's first test flights, the switch that regulates fuel flow to the engines on the MAX was unintentionally and unknowingly triggered by the Boeing test pilot flying the aircraft by shutting off fuel to the number one engine, the Committee has learned[302] The engine shut down.[303] Fortunately, the aircraft returned safely without incident. The episode was the result of a design issue in the fuel valve switch manufactured by a Boeing subcontractor.[304] Although there was reluctance on the part of some senior Boeing officials to address and adequately fix this issue at the time, according to one former Boeing employee, they eventually did.[305] The details of this episode were confirmed by the former 737 MAX General Manager Keith Leverkuhn in a transcribed interview with Committee staff. [306] One year after the "engine out" incident, in March 2017, the 737 MAX received its airworthiness certificate from the FAA.[307]

In May 2017, two months after it received its airworthiness certificate from the FAA and just weeks before its first 737 MAX delivery, Boeing halted the test flights of the 737 MAX, effectively grounding the entire fleet, which at the time numbered just 21 aircraft.[308] The manufacturer of its new engines, CFM International, reported that its supplier for low pressure turbine rotor discs may have delivered a batch of defective parts to Boeing.[309] In a statement, Boeing said: "Out of an abundance of caution, we decided to temporarily suspend MAX flights. The step is consistent with our priority focus on safety for all who use and fly our products."[310] Boeing sent an estimated 30 engines back to CFM International, a joint venture between General Electric and Safran, a French manufacturer, for inspection.[311] The temporary grounding was short lived.[312] On May 16, 2017, less than one week after the MAX was grounded, Boeing made its first delivery of the new 737 MAX aircraft to Malindo Air.[313]

These two incidents show that Boeing did take appropriate steps in some cases, even if it did so reluctantly. However, the 737 MAX program was not the only Boeing commercial aircraft program suffering from technical and safety related issues. While many of the problems discovered on the 737 MAX program were design related issues, years before the 737 MAX program started, there were numerous warning signs about the quality and safety of Boeing's production and

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[302] Confidential conversation with former Boeing employee and Democratic Committee staff, April 29, 2019.
[303] Ibid.
[304] Ibid.
[305] Ibid
[306] Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020.
[307] "Boeing 737 MAX 8 Earns FAA Certification," *Press Release*, Boeing Commercial Airplanes, March 9, 2017, accessed here: https://boeing.mediaroom.com/2017-03-09-Boeing-737-MAX-8-Earns-FAA-Certification
[308] Alwyn Scott, "Boeing suspends 737 MAX flights due to engine issue," *Reuters*,, May 10, 2017, accessed here: https://www.reuters.com/article/us-boeing-737max-engine-idUSKBN1862O9
[309] See: Stephen Trimble, "Boeing delivers first 737 Max," *FlightGlobal*, May 16, 2017, accessed here: https://www.flightglobal.com/systems-and-interiors/boeing-delivers-first-737-max-/124050.article and Alwyn Scott, "Boeing suspends 737 MAX flights due to engine issue," *Reuters*,, May 10, 2017, accessed here: https://www.reuters.com/article/us-boeing-737max-engine-idUSKBN1862O9
[310] Jon Ostrower, "Boeing grounds 737 MAX flights for engine inspections," *CNN Business*, May 10, 2017, accessed here: https://money.cnn.com/2017/05/10/news/companies/boeing-halts-737-max-flying-engine-issue/index.html
[311] Ibid.
[312] Jon Ostrower, "Boeing cleared to fly the 737 Max, delivers first jet," *CNN Business*, May 17, 2017, accessed here: https://money.cnn.com/2017/05/16/news/companies/boeing-737-max-first-delivery/index.html
[313] "Boeing, Malindo Air Celebrate First 737 MAX Delivery," Press Release, Boeing Commercial Airplanes, May 16, 2017, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=129894

manufacturing processes across multiple Boeing Commercial Airplanes (BCA) programs. Beginning in 2010, for example, the FAA discovered 193 instances of faulty wiring installation on Boeing's 787 Dreamliner.[314] Additional inspections found 149 more instances of faulty wiring in addition to fuel leaks caused by the improper installation of "lock wires."[315] Wiring harnesses were also discovered to have been installed incorrectly.[316]

And then the 787 was grounded worldwide in 2013 after the airplane's lithium battery—a key part of the 787 electrical system—self-ignited on two separate occasions, creating an unacceptable risk that a lithium-battery-fed fire would consume a 787 in flight before the crew could land and evacuate the airplane.[317] The grounding would last for three and a half months, until Boeing decided to enclose the airplane battery in a titanium box that would contain any fire.[318] Investigating the 787 battery incident that occurred in the United States—a fire on board a Japan Airlines 787-8 after landing in Boston—the National Transportation Safety Board concluded Boeing performed an incomplete system safety assessment that failed to consider the most severe effects of a battery fire and that the FAA's review of the assessment failed to identify this shortcoming.[319] The Safety Board found that "[t]he [Japan Airlines] incident resulted from Boeing's failure to incorporate design requirements to mitigate the most severe effects of an internal short circuit within [a] battery cell and the Federal Aviation Administration's failure to identify this design deficiency during the type design certification process."[320]

While these issues occurred on a different Boeing model airplane, the Committee's investigation found that in multiple other instances over the lifetime of the 737 MAX program—and even beyond the 737 MAX program—Boeing engaged in conduct that ran contrary to sound aviation engineering practices and in several cases attempted to shield critical information from Federal regulators, Boeing's customers, and 737 MAX pilots, jeopardizing the safety of the flying public.

Boeing-FAA Settlement Agreement

By 2015, the FAA was pursuing 13 separate enforcement investigations against Boeing related to multiple BCA programs, including the 737 program.[321] Most of these cases involved failures by Boeing to take corrective actions to known problems, to take appropriate actions to

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[314] Committee staff briefing by the Federal Aviation Administration (FAA), July 12, 2019.
[315] Ibid.
[316] Ibid.
[317] See: Emergency Airworthiness Directive, No. 2013-02-51, Federal Aviation Administration, January 16, 2013, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAD.nsf/0/8a1a8dc3135b60dd86257af60004cf4a/%24FILE/2013-02-51_Emergency.pdf and Christopher Drew, Jad Mouawad, and Matthew L. Wald, "F.A.A. Grounds U.S.-Operated Boeing 787s," *New York Times*, January 16, 2013, accessed here: https://www.nytimes.com/2013/01/17/business/faa-orders-grounding-of-us-operated-boeing-787s.html
[318] "FAA Order Formally Lifts Boeing 787 Dreamliner Grounding," *The Associated Press,* April 25, 2013, accessed here: https://www.usatoday.com/story/travel/flights/2013/04/25/faa-boeing-787-dreamliner/2113463/
[319] "Aircraft Incident Report: Auxiliary Power Unit Battery Fire, Japan Airlines Boeing 787-8, JA829J, Boston, Massachusetts, January 7, 2013," Incident Report, NTSB/AIR-14/01, National Transportation Safety Board (NTSB), November 21, 2014, at 78-79, accessed here: https://www.ntsb.gov/investigations/accidentreports/reports/air1401.pdf
[320] Ibid., p. 79.
[321] Andy Pasztor and Robert Wall, "Boeing Accepts FAA Penalties Over Quality Control," *Wall Street Journal,* December 22, 20015, accessed here: https://www.wsj.com/articles/boeing-faa-reach-settlement-over-safety-compliance-concerns-1450794214

prevent known problems from reoccurring, and being tardy in its communications with the FAA once Boeing learned these issues existed.[322] These problems affected multiple BCA programs spanning multiple years and involving issues related to fuel tank flammability, millions of incorrectly shaped fasteners, improperly installed decompression panels, tools being left inside airplanes (known as foreign object debris or "FOD"), inappropriate installation of cargo doors on Boeing 777 aircraft, and Boeing subcontractors falsifying certification records, among other issues.[323]

In an attempt to resolve the "multiple pending and potential enforcement cases," Boeing and the FAA entered into a settlement agreement that went into effect on January 1, 2016.[324] The agreement implemented corrective actions to ensure the issues identified by the FAA were corrected and that systemic changes were instituted so that they would not emerge again. The agreement settled two civil enforcement cases that the FAA had initiated and the 11 other enforcement investigations that the FAA had been pursuing against Boeing.[325] As part of the agreement, Boeing was obligated to implement various procedures to help improve the quality of its production and manufacturing processes. This included implementing a Safety Management Systems (SMS) plan that BCA developed to meet internationally accepted standards throughout the company's activities.[326] The FAA Administrator at the time, Michael Huerta responded by saying: "Boeing has agreed to implement improvements in its design, planning, production and maintenance planning processes and has already implemented several of these improvements."[327]

As part of the settlement agreement, Boeing initially paid $12 million and faces the potential for an additional $24 million in penalties through the life of the five-year settlement agreement that is set to conclude in December 2020.[328] Boeing, however, accumulated more than $80 billion in gross profits during the five-year period in which most of these violations occurred, from 2010 to 2015.[329] Considering that Boeing's gross profits peaked in 2018, reaching nearly $20 billion in that year alone, the $12 million fine and the proposed potential future fines of $24 million—characterized by the FAA as "stiff penalties" —appear insignificant.[330]

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[322] Michael Laris, "Long before the Max disasters, Boeing had a history of failing to fix safety problems," *Washington Post*, June 17, 2019, accessed here: https://www.washingtonpost.com/local/trafficandcommuting/long-before-the-max-disasters-boeing-had-a-history-of-failing-to-fix-safety-problems/2019/06/26/b4f5f720-86ee-11e9-a870-b9c411dc4312_story.html

[323] Committee staff briefing by the Federal Aviation Administration (FAA), July 12, 2019.

[324] See: FAA-Boeing Settlement Agreement (Redacted Version), Signed by Reginald C. Govan, Chief Counsel, Federal Aviation Administration (FAA) and Brett Gerry, Vice President and Assistant General Counsel, Boeing Commercial Airplanes (BCA), December 2015, BATES Number: FAA T&I 6902-6930 (On file with the Committee), and "Boeing Agrees to Pay $12 Million and Enhance its Compliance Systems to Settle Enforcement Cases" Press Release, Federal Aviation Administration (FAA), Dec. 22, 2015, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=19875

[325] Committee staff briefing by the Federal Aviation Administration (FAA), July 12, 2019.

[326] "Boeing Agrees to Pay $12 Million and Enhance its Compliance Systems to Settle Enforcement Cases" Press Release, Federal Aviation Administration, Dec. 22, 2015, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=19875

[327] "Boeing Agrees to Pay $12 Million and Enhance its Compliance Systems to Settle Enforcement Cases," Press Release, Federal Aviation Administration, December 22, 2018, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=19875

[328] Ibid.

[329] "Boeing Gross Profit 2006-2019," *Macrotrends*, accessed here: https://www.macrotrends.net/stocks/charts/BA/boeing/gross-profit

[330] "Boeing Agrees to Pay $12 Million and Enhance its Compliance Systems to Settle Enforcement Cases," Press Release, Federal Aviation Administration, December 22, 2018, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=19875

Moreover, in June 2019, the *Washington Post* reported that Boeing had failed to meet some of its obligations under the settlement agreement in the previous three and a half years and that the FAA has so far chosen not to invoke enforcement provisions against Boeing that could subject the company to the additional $24 million in penalties.[331]

The Washington Post
June 17, 2019

"[T]OP BOEING EMPLOYEES WHO WERE SUPPOSED TO BE REPRESENTING THE FAA AT TIMES AGGRESSIVELY CHAMPIONED THE COMPANY'S INTERESTS INSTEAD."

In addition, since Boeing signed the settlement agreement with FAA, it has repeated some of the same problems that the FAA agreement sought to force the company to correct. Last year, for instance, the U.S. Air Force temporarily halted deliveries of Boeing's KC-46 Pegasus tanker twice because of foreign object debris found in the aircraft as a result of deficiencies in the manufacturing process.[332] The KC-46 tanker is based on the Boeing 767 aircraft. In February 2020, it was reported that foreign object debris was also found in the fuel tanks of dozens of undelivered 737 MAX aircraft. [333] Boeing's inability to correct such critical systematic manufacturing failures is extremely troubling.

FAA's Organization Designation Authorization Program

The noted decline in product quality and safety culture at Boeing outlined above coincided with the evolution in the FAA's oversight structure of the aviation industry. In 2005, the FAA restructured its decades old designee program and implemented a new designee oversight program known as the Organization Designation Authorization (ODA) program that enhanced the authority that FAA granted to aircraft manufacturers, such as Boeing, to perform FAA mandated certification activities. It is worth noting that as part of the Committee's 737 MAX investigation the Committee has only investigated Boeing's ODA program and not those of other aircraft manufacturers.

However, the problems with Boeing's ODA program are clearly significant. The enforcement issues investigated by the FAA that resulted in the 2015 settlement agreement, for instance, found that Boeing employees who were supposed to be representing the interests of the FAA under the ODA program were instead representing the interests of Boeing. As part of the settlement agreement the FAA mandated that the individuals holding the top two positions in the Boeing ODA program "will not advocate" for Boeing "to avoid any potential conflicts."[334] As the

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[331] Michael Laris, "Long before the Max disasters, Boeing had a history of failing to fix safety problems," *Washington Post*, June 17, 2019, accessed here: https://www.washingtonpost.com/local/trafficandcommuting/long-before-the-max-disasters-boeing-had-a-history-of-failing-to-fix-safety-problems/2019/06/26/b4f5f720-86ee-11e9-a870-b9c411dc4312_story.html

[332] Stephen Losey, "Air Force again halts KC-46 deliveries after more debris found," *Air Force Times*, April 2, 2019, accessed here: https://www.airforcetimes.com/news/your-air-force/2019/04/02/air-force-again-halts-kc-46-deliveries-after-more-debris-found

[333] Kanishka Singh and Eric M. Johnson, "Boeing finds debris in fuel tanks of many undelivered 737 MAX jets," *Reuters*, February 22, 2020, accessed here: https://www.reuters.com/article/us-boeing-737max-debris/boeing-finds-debris-in-fuel-tanks-of-many-undelivered-737-max-jets-idUSKCN20G08X

[334] FAA-Boeing Settlement Agreement (Redacted Version), Signed by Reginald C. Govan, Chief Counsel, Federal Aviation Administration (FAA) and Brett Gerry, Vice President and Assistant General Counsel, Boeing Commercial Airplanes (BCA), December 2015, p. 6, BATES Number: FAA T&I 6902-6930. (On file with the Committee).

Washington Post observed: "[T]op Boeing employees who were supposed to be representing the FAA at times aggressively championed the company's interests instead."[335]

In addition, the Committee's own investigation has revealed that Boeing designees involved in critical issues regarding the certification of the 737 MAX program failed to keep the FAA adequately informed of key issues, although these same designees did attempt to raise these issues internally at Boeing.

The Committee's investigation has shown that these and other significant and systemic issues still exist at Boeing and were prevalent during a critical period of the MAX's certification process. These production and manufacturing issues, taken together with the aforementioned design, development, and certification issues paint a deeply disturbing picture of cultural issues at Boeing regarding safety, quality control, and transparency that will take a long time and serious efforts to thoroughly resolve.

In many cases, the FAA designee structure under the ODA program has also led to dwindling effectiveness of the FAA's oversight authority that has adversely impacted safety. These are not just the findings of the Committee's investigation but have been clearly identified by the FAA's recent "safety culture" survey of its own Aviation Safety (AVS) employees.[336] In that survey, for instance, 43 percent of AVS-wide respondents said the FAA does **not** appropriately delegate certification activities to external FAA designees and 54 percent of FAA employees in the Aircraft Certification Service (AIR) —a part of AVS—felt the same way.[337] In addition, 56 percent of AIR employees believed there was too much external influence on the agency and that it was having an impact on safety.[338]

These and other issues at the FAA have hampered the agency's ability to identify and effectively correct quality and safety issues at Boeing. It is important to understand these issues and the changes in the FAA's designee oversight structure to grasp the full extent of the problems that emerged in the 737 MAX program and that the Committee has uncovered during its investigation.

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[335] Michael Laris, "Long before the Max disasters, Boeing had a history of failing to fix safety problems," *Washington Post*, June 17, 2019, accessed here: https://www.washingtonpost.com/local/trafficandcommuting/long-before-the-max-disasters-boeing-had-a-history-of-failing-to-fix-safety-problems/2019/06/26/b4f5f720-86ee-11e9-a870-b9c411dc4312_story.html

[336] "Safety Culture Assessment Report," Federal Aviation Administration, Aviation Safety Organization (AVS), conducted and prepared by The MITRE Corporation, (DRAFT) February 28, 2020, (Hereafter referred to as "FAA Safety Culture Survey"). (On file with the Committee).

[337] Ibid.

[338] Ibid.

4. FAA Oversight and Delegation of Authority

-FAA Oversight and Delegation of Authority-

INVESTIGATIVE FINDINGS

- Excessive FAA delegation of certification functions to Boeing on the 737 MAX eroded FAA's oversight effectiveness and the safety of the public.

- Boeing Authorized Representatives (ARs)—Boeing employees acting as representatives of the FAA or performing certification functions on behalf of the FAA—were impaired from acting independently of the company in regard to the certification of the 737 MAX.

- The Committee identified multiple cases where Boeing ARs did not relay important safety-related information to the FAA because there was no requirement to do so, hindering a more comprehensive FAA review of the 737 MAX which may have improved the safety of the airplane and potentially prevented the two fatal MAX accidents.

- In some cases, FAA senior managers acted against the safety recommendations from FAA's own technical experts to support Boeing's business interests. This included a rudder cable issue on the 737 MAX and a lightning protection issue on the 787 Dreamliner.[339]

- In November 2016, an internal Boeing survey found that a full 39 percent of Boeing ARs said they had experienced "undue pressure," pointing to disturbing cultural issues that Boeing must confront to eradicate conditions that undermine safety.[340]

- In February 2020, an FAA contractor published the results of FAA's own (draft) "safety culture survey" of employees in its Aviation Safety Organization (AVS). The results point to an institution in dire need of immediate repair. The "key takeaway" from the survey and the contractor's interviews with AVS executives, employees, and other stakeholders was that "AVS senior leadership's response to and management of industry pressure is at the heart of the organization's core safety culture challenges: lack of trust, inconsistent accountability, FAA role confusion, and the perception that AVS is moving further away from its safety mission."[341] Nearly half of the "survey respondents **disagreed** that FAA makes data-driven decisions about safety regardless of external pressure."[342] These findings mirror the Committee's own revelations in this report.

- The Committee's investigation has identified sweeping and systemic problems revolving around the ability of the FAA to effectively engage in regulatory activity and robust oversight of Boeing to ensure the safety of the flying public and the aviation community.

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[339] Letter from Chair DeFazio and Subcommittee on Aviation Chair Larsen to FAA Administrator Dickson regarding 737 MAX Rudder Cable Issue and 787 Dreamliner Lightning Protection Issues, November 7, 2019, accessed here: https://transportation.house.gov/imo/media/doc/DeFazio,%20Larsen%20Letter%20to%20FAA%20re%20rudder%20cables,%20lightning%20covers.pdf

[340] "Undue Pressure: Key Learnings and Next Steps," Boeing Commercial Airplanes (BCA), November 2016, pp. 144-151, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[341] "Safety Culture Assessment Report," Federal Aviation Administration, Aviation Safety Organization (AVS), conducted and prepared by The MITRE Corporation, (DRAFT) February 28, 2020, (Hereafter referred to as "FAA Safety Culture Survey"). (On file with the Committee).

[342] Ibid.

Delegation Authority Background

All U.S. manufactured aircraft and aviation products are subject to certification by the FAA prior to their sale and use in the United States.[343] The FAA is responsible for regulating aviation safety, which includes approving the design and manufacture of new aircraft and aviation products before they enter air commerce.[344] To leverage its significant but limited staff resources, the FAA is authorized by statute to delegate certification and other functions of the agency to qualified individuals,[345] including through the Organization Designation Authorization (ODA) program.[346] An Organization Designation Authorization includes both an ODA Holder—the parent organization to which the FAA grants an ODA Letter of Designation—and an ODA unit that consists of individuals within the ODA Holder's organization who perform the FAA-authorized functions.[347] Individuals granted this specific designee authority are referred to throughout this report as authorized representatives or ARs.[348]

Civil aviation authorities worldwide—not just the FAA—administer delegation programs to leverage the product-specific knowledge of manufacturers' qualified employees to determine a product's compliance with government regulations. The FAA has relied on delegation authority for more than 50 years. However, it has come to be more heavily used over time as airplanes, engines, and their constituent systems have become increasingly complex. Figure 1 below illustrates the development and evolution of FAA's organizational delegation since the inception of FAA delegation authority to industry.

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[343] 49 U.S.C. § 44702, "Issuance of certificates," accessed here: https://www.govinfo.gov/app/details/USCODE-2011-title49/USCODE-2011-title49-subtitleVII-partA-subpartiii-chap447-sec44702/summary

[344] See: 49 U.S.C. § 44702, "Issuance of certificates," accessed here: https://www.govinfo.gov/app/details/USCODE-2011-title49/USCODE-2011-title49-subtitleVII-partA-subpartiii-chap447-sec44702/summary; 49 U.S.C. § 44704, "Type certificates, production certificates, airworthiness certificates, and design and production organization certificates," accessed here: https://www.govinfo.gov/app/details/USCODE-2015-title49/USCODE-2015-title49-subtitleVII-partA-subpartiii-chap447-sec44704; and "Aviation Manufacturing: Status of FAA's Efforts to Improve Certification and Regulatory Consistency," U.S. Government Accountability Office (GAO), GAO-14-829T, July 31, 2014, (Hereafter referred to as GAO-14-829T), accessed here: https://www.gao.gov/assets/670/665131.pdf

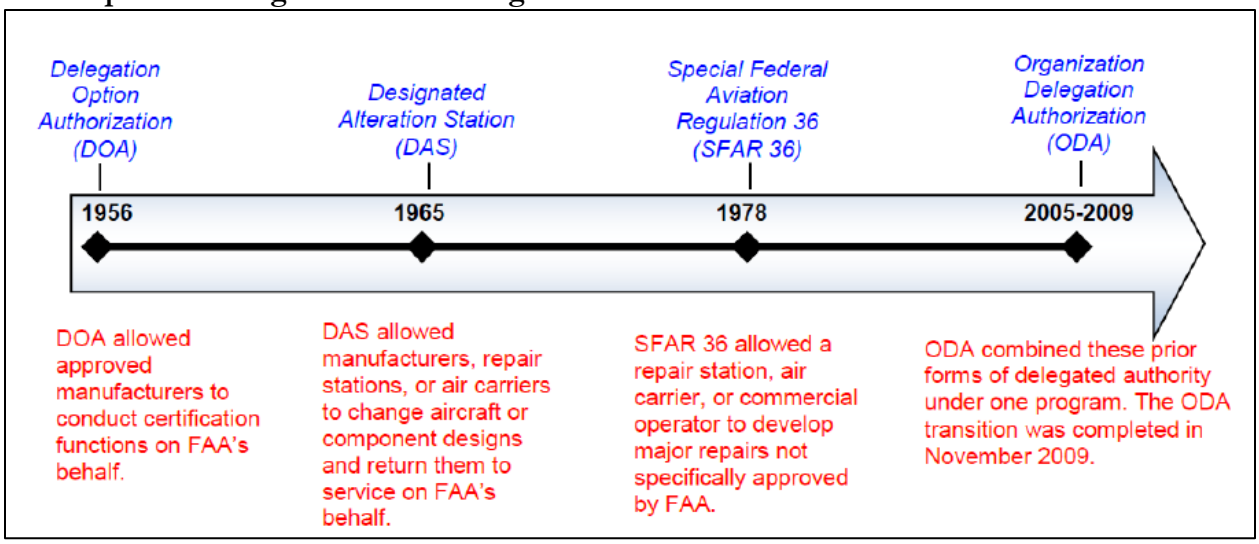
[345] 49 U.S.C. § 44702(d).

[346] The regulations addressing the ODA program are found in Title 14 of the Code of Federal Regulations (14 CFR) part 183, subpart D, sections 183.41 through 183.67. See: 14 CFR 183, "Representatives of the Administrator," Subpart D, "Organization Designation Authorization," accessed here: https://www.govinfo.gov/app/details/CFR-2011-title14-vol3/CFR-2011-title14-vol3-part183 and "Delegated Organizations," Federal Aviation Administration (FAA), accessed here: https://www.faa.gov/other_visit/aviation_industry/designees_delegations/delegated_organizations

[347] Ibid.

[348] The FAA's designees had been termed designated engineering representatives (DERs), but during the years the 737 MAX underwent certification they were called authorized representatives (ARs). Most recently, the term used to describe these designees has changed to engineering unit members (E-UMs). Throughout this report, these designees are referred to as authorized representatives (ARs), since that was the term used for these designees during the certification of the 737 MAX.

Development of Organizational Delegation


Delegation Option Authorization (DOA)
Designated Alteration Station (DAS)
Special Federal Aviation Regulation 36 (SFAR 36)
Organization Delegation Authorization (ODA)
1956
1965
1978
2005-2009
DOA allowed approved manufacturers to conduct certification functions on FAA's behalf.
DAS allowed manufacturers, repair stations, or air carriers to change aircraft or component designs and return them to service on FAA's behalf.
SFAR 36 allowed a repair station, air carrier, or commercial operator to develop major repairs not specifically approved by FAA.
ODA combined these prior forms of delegated authority under one program. The ODA transition was completed in November 2009.

Source: Department of Transportation, Office of Inspector General, Audit Report AV-2016-001[349]

The current iteration of the ODA program was established in November 2005 and fully implemented four years later as the means by which FAA grants designee authority to organizations or companies to perform certain functions on its behalf.[350] This includes determining whether an aircraft, engine, or component meets applicable requirements for issuance of an FAA certificate.[351] The ODA program combined various FAA delegation authorities to standardize the FAA's oversight of ODA designees.[352] In particular, the ODA program (1) expanded the scope of approved tasks available to organizational designees; (2) increased the number of organizations eligible for organizational designee authorizations; and (3) established a more comprehensive, systems-based approach to managing designated organizations.[353]

The ODA program was intended to allow the FAA to delegate certification of well-understood, non-critical, or low-risk designs so that the FAA can remain directly involved in review and approval of higher-risk items, such as safety-critical or "new and novel" designs.[354] This has

[349] "FAA Lacks an Effective Staffing Model and Risk-Based Oversight Process for Organization Designation Authorization," Audit Report, Report Number: AV-2016-001, U.S. Department of Transportation (DOT), Office of Inspector General (OIG), October 15, 2015 (Hereafter referred to as "DOT OIG Audit Report AV-2016-001"), accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20ODA%20Final%20Report%5E10-15-15.pdf

[350] "Establishment of Organization Designation Authorization Program," Federal Aviation Administration (FAA), Final Rule, Federal Register, Vol. 70, No. 197, 70 FR 59931, October 13, 2005, (Hereafter referred to as "Establishment of ODA Program," 70 FR 59931), accessed here: https://www.federalregister.gov/documents/2005/10/13/05-20470/establishment-of-organization-designation-authorization-program and DOT OIG Audit Report AV-2016-001.

[351] See GAO-14-829T, p. 5, for a description of the types of certifications that FAA oversees.

[352] DOT OIG Audit Report AV-2016-001.

[353] "Establishment of ODA Program," 70 FR 59931.

[354] See Prepared Statement of Daniel K. Elwell, FAA Acting Administrator, Hearing titled, "Status of the Boeing 737 MAX," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, and Daniel K. Elwell response to questions from Hon. Henry C. "Hank" Johnson , p. 21 and p. 85, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

allowed FAA designees to engage in a broad range of actions performing more than 90 percent of the total scope of FAA certification activities in many instances.[355] However, various investigations of the 737 MAX, including the Committee's own investigation, have concluded that FAA delegated some certification activities to Boeing that it should have retained. In the case of the 737 MAX, in 2013, the FAA originally delegated 28 of 87 tasks to Boeing.[356] However, this number rose to 79 of 91 activities by November 2016, four months prior to final certification of the 737 MAX aircraft.[357]

Once a designee establishes through inspections and tests that an aviation product comports with FAA standards, the FAA is supposed to conduct a risk-based review of the designee's work and issue a type certificate if the product meets minimum safety standards.[358] As the Special Committee to Review the Federal Aviation Administration's Aircraft Certification Process, established by the Secretary of Transportation in response to the MAX crashes, wrote: "Regardless of whether it is FAA staff or FAA-authorized designees responsible for certain aspects of a certification program, the applicant is always required to show compliance, while the FAA is responsible to find compliance."[359] The FAA further acknowledges that, "[They're] responsible for the safety of civil aviation."[360] In summary, the FAA bears ultimate responsibility for ensuring new aircraft designs are safe and comply with airworthiness standards.

ODA Program Effectiveness and Concerns

Two months before the Lion Air crash, the FAA touted the aviation industry's impressive safety record over the preceding decade in a fact sheet that boasted: "The commercial aviation system in the United States operates at an unprecedented level of safety. During the past 20 years, commercial aviation fatalities in the U.S. have decreased by 95 percent as measured by fatalities per 100 million passengers."[361]

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[355] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Department of Transportation (DOT), Office of Inspector General (OIG), Report No. AV2020037, June 29, 2020, p. 3, (Hereafter referred to as DOT OIG Report No. AV2020037), accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf. The DOT OIG wrote, "Designees can perform a substantial amount of critical certification work on FAA's behalf. For example, according to FAA data, in 2018 four U.S. aircraft manufacturers approved about 94 percent of the certification activities for their own aircraft."

[356] DOT OIG Report No. AV2020037, p. 15.

[357] Ibid.

[358] FAA issues a type certificate that approves a product's design when an applicant has demonstrated that the product complies with applicable standards defined in 14 CFR. The type certificate is the foundation for other FAA approvals, including production and airworthiness approvals. See "Type Certification," FAA Order 8110.4C, CHG 6, Federal Aviation Administration (FAA), Department of Transportation (DOT), March 6, 2017, accessed here: https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8110_4C_Chg_6.pdf and "Establishment of Organization Designation Authorization Procedures," Notice of proposed rulemaking (NPRM), Federal Register, Vol. 69, No. 13, 69 FR 2969, Federal Aviation Administration (FAA), January 21, 2004, accessed here: https://www.federalregister.gov/d/04-1133/p-101

[359] "Official Report of the Special Committee to Review the Federal Aviation Administration's Aircraft Certification Process," Department of Transportation (DOT), January 16, 2020, (Hereafter referred to as "DOT Special Committee Report"), p. 22., accessed here: https://www.transportation.gov/sites/dot.gov/files/2020-01/scc-final-report.pdf

[360] "What we do," Federal Aviation Administration, accessed here: https://www.faa.gov/about/mission/activities

[361] "Fact Sheet – Out Front on Airline Safety: Two Decades of Continuous Evolution," Federal Aviation Administration, August 2, 2018, accessed here: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22975

From 2010 to 2018, U.S. air carriers suffered just one passenger fatality.[362] The number of commercial flights flown annually in the U.S. over this time period ranged between about 10.5 million and 11 million.[363] In 2019 alone, more than 811 million passengers boarded domestic flights on U.S. airlines, continuing a decade-long trend of annual increases.[364] Even after the Lion Air and Ethiopian Airlines crashes, the FAA repeatedly took the opportunity to focus on this past safety record while reluctantly acknowledging problems in the certification of the 737 MAX. In May 2019, for example, Dan Elwell, the then-Acting FAA Administrator, told an audience of international aviation authorities in Texas: "One fatality in 10 years. I'll say it again: 90 million flights, 7 billion passengers. We've had one fatality."[365]

Unfortunately, the nation's successful past aviation safety record eventually led to complacency by both Boeing and the FAA. This was one factor that contributed to an overconfidence in the certification system that promulgated a culture that equated compliance to safety.

The Committee's investigation found fundamental flaws in the implementation and operation of the ODA program under which the FAA designated Boeing to act on its behalf. In several cases, FAA provided inadequate oversight and instead deferred to Boeing, leading to the production of airplanes with significant safety problems. These included the 737 MAX with its new Maneuvering Characteristics Augmentation System (MCAS) feature as well as the 787 Dreamliner, which in January 2013, experienced problems with on-board fires caused by the airplane's new lithium batteries. Both of these aircraft models—developed under the ODA program—were grounded because of safety concerns.[366] Not all of the issues with the 787 Dreamliner or 737 MAX can be attributed to the ODA program. However, the lack of robust FAA oversight certainly contributed to the problems that resulted in both the 787 Dreamliner incidents and 737 MAX crashes.

The Department of Transportation (DOT) Office of Inspector General (OIG) recognized this as early as 2012, in its Fiscal Year 2012 Top Management Challenges report, where it found significant weaknesses in the FAA's ODA program. Among the key findings:

> FAA has not adequately trained engineers on their new enforcement responsibilities under ODA, and some FAA certification offices have not effectively tracked or addressed poorly performing ODA

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[362] "Safety Record of U.S. Air Carriers," Airlines for America, accessed here: https://www.airlines.org/dataset/safety-record-of-u-s-air-carriers

[363] "Air Traffic By the Numbers," Federal Aviation Administration, June 2019, p.6, accessed here: https://www.faa.gov/air_traffic/by_the_numbers/media/Air_Traffic_by_the_Numbers_2019.pdf

[364] See "Passengers: All Carriers - All Airports," Bureau of Transportation Statistics, U.S. Department of Transportation, accessed here: https://www.transtats.bts.gov/Data_Elements.aspx?Data=1

[365] Michael Laris, "Long before the Max disasters, Boeing had a history of failing to fix safety problems," *The Washington Post,* June 27, 2019, accessed here: https://www.washingtonpost.com/local/trafficandcommuting/long-before-the-max-disasters-boeing-had-a-history-of-failing-to-fix-safety-problems/2019/06/26/b4f5f720-86ee-11e9-a870-b9c411dc4312_story.html

[366] Gwyn Topham, "Boeing Dreamliner: US joins Japan in grounding 787s," *The Guardian*, January 17, 2013, accessed here: https://www.theguardian.com/business/2013/jan/16/japanese-carriers-ground-24-boeing-787s

personnel. In addition, ODA significantly reduced FAA's role in approving individuals who perform work on FAA's behalf.[367]

Studies from government and industry stakeholders have long raised questions about the effectiveness of FAA's certification process in making compliance decisions during certification.[368] The 2012 FAA Modernization and Reform Act, for instance, required FAA to work with industry to resolve numerous issues related to its certification processes and varying interpretations and applications of its regulations.[369] In response, the FAA chartered a rulemaking committee in April 2012 to address this requirement.[370] Based on the committee's recommendations, the FAA developed initiatives that included improving and expanding its ODA program and rolled implementation of these initiatives into a larger organizational transformation of its Aircraft Certification Service (AIR).[371]

As part of this transformation, AIR sought to advance its safety mission and related outcomes by interrelated means such as enhancing the accountability framework, adopting risk-based decision making, implementing an information management strategy, and strengthening industry partnerships, among other initiatives.[372] AIR anticipated that the successful implementation of its transformation would enable it to better manage operational safety risk, reduce the time for approval decisions, increase the schedule predictability of approval decisions, and increase AIR's productivity.[373] The FAA implemented the AIR reorganization in July 2017, which included the establishment of the Systems Oversight Division (AIR-800) that is responsible for managing FAA's

[367] "Top Management Challenges for Fiscal Year 2012," Report Number: PT-2012-006, Department of Transportation (DOT), Office of Inspector General (OIG), November 15, 2011, p. 7, accessed here: https://www.faa.gov/about/plans_reports/media/FY12TopMgmtChallengesFINAL.pdf
[368] "Aviation Certification: Issues Related to Domestic and Foreign Approval of U.S. Aviation Products," GAO-15-550T, Government Accountability Office (GAO), April, 21, 2015, (Hereafter referred to as GAO-15-550T), accessed here: https://www.gao.gov/products/gao-15-550t; and "Aviation Certification: FAA Has Made Continued Progress in Improving Its Processes for U.S. Aviation Products," GAO-17-508T, Government Accountability Office (GAO), March, 23, 2017, accessed here: https://www.gao.gov/products/GAO-17-508T
[369] FAA Modernization and Reform Act of 2012, Pub. L. No. 112-95, §§ 312 and 313, 126 Stat. 11, 66, 67 (2012).
[370] See Ali Bahrami, Manager, FAA Transport Airplane Directorate, and Christine Thompson, Lead ODA Project Administrator Advisor, Boeing Commercial Airplanes; Aircraft Certification Process Review and Reform Aviation Rulemaking Committee Co-Chairs; "A Report from the Aircraft Certification Process Review and Reform Aviation Rulemaking Committee to the Federal Aviation Administration: Recommendations on the Assessment of the Certification and Approval Process," Department of Transportation (DOT), Federal Aviation Administration (FAA), May 22, 2012, accessed here: https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/acprrarc-4202012.pdf
[371] See "DOT Special Committee Report," pp. 27-28 and GAO-17-508T.
[372] "Comprehensive Strategic Plan for AIR Transformation," Federal Aviation Administration (FAA), July 2018, p. 4, accessed here: https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/air/transformation/media/comprehensive_strategic_plan.pdf
[373] Ibid., p. 6.

designees.[374] This implementation occurred four months after the FAA's certification of the 737 MAX.[375]

However, the FAA's recent safety culture survey points to continuing problems with the FAA's management of designees and its ability to ensure the FAA's fundamental mission of aviation safety is being duly and fully met. "Many focus group participants," the survey found, "believe that the Organization Designation Authorization (ODA) Model is causing FAA to move further away from its safety mission and results in confusion about the FAA's roles."[376] Furthermore, the survey found that there was "a general concern that the FAA" … "has delegated too much authority to industry which negatively impacts the safety of the National Airspace."[377]

In 2015, as FAA proceeded to make operational and organizational changes affecting its expanding ODA program, GAO reported that while industry stakeholders emphasized the need for FAA to expand its ODA program, industry union representatives expressed concerns about FAA's lack of resources to effectively do so.[378] Specifically, union representatives said that FAA already did not have enough inspectors and engineers to provide the proper surveillance of existing designees.[379]

Further, the DOT OIG found that FAA lacked a comprehensive process for determining adequate staffing levels for effective ODA oversight and that inspectors and engineers were not fully performing risk-based oversight due to the lack of adequate guidance, risk-based tools, and robust data analysis.[380] As a result, FAA's ODA oversight findings were often not related to issues that could directly impact the potential loss of critical systems or other safety concerns, but rather focused on minor issues such as paperwork errors.[381]

Related to these issues, the unions representing aviation engineers, safety specialists, and other personnel had deep concerns about the reorganization of the AIR and the impact it would have on the FAA's ability to conduct thorough oversight of Boeing. In February 2017, the National Air Traffic Controllers Association (NATCA), the Professional Aviation Safety Specialists (PASS), and the American Federation of State, County & Municipal Employees (AFSCME) published a report titled: "Aircraft Certification "Transformation" Pre-Decisional Involvement Report: Union Recommendations and Dissenting Opinion."[382] Among its observations, the report noted: "Today

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[374] "Air Transformation Timeline," Federal Aviation Administration (FAA), May 15, 2018, accessed here: https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/air/transformation/media/AIR_transformation_timeline.pdf. For additional information on AIR transformation see "Aircraft Certification Service (AIR) Transformation," Federal Aviation Administration, accessed here: https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/air/transformation/

[375] "Type Certificate Data Sheet A16WE," Federal Aviation Administration, Department of Transportation, March 8, 2017, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf/0/0970d54d00efbb9a862580de006a83cc/$FILE/A16WE_Rev_58.pdf

[376] FAA Safety Culture Survey.

[377] Ibid.

[378] GAO-15-550T, pp. 7-8.

[379] Ibid.

[380] DOT OIG Audit Report AV-2016-001, pp. 4-6.

[381] Ibid., p.6.

[382] "Aircraft Certification "Transformation" Pre-Decisional Involvement Report: Union Recommendations and Dissenting Opinion," National Air Traffic Controllers Association (NATCA), the Professional Aviation Safety

the Boeing Aviation Safety Oversight Office (BASOO) is focused on meeting Boeing certification needs and does not allocate significant resources to oversight." The report said the FAA plan proposed "a 60 percent reduction in engineering involvement in certification oversight."[383]

Furthermore, the report found:

> The shifting of resources from direct up front oversight at the high risk point in the certification, to post certification audits and correcting unsafe conditions that are discovered on in-service aircraft is a fundamentally flawed concept and is not based upon data or risk analysis. This concept is based on the premise the ODA will independently make correct compliance findings without involvement of the second set of eyes provided by FAA engineers and inspectors. The assumption a "for profit" company that is faced with significant financial incentive will always make appropriate compliance findings contradicts human nature, and is not supported by experience in other industries and the performance of the Boeing ODA. The consequences of ODA approval of noncompliant or unsafe designs would result in introduction of large numbers of airplanes in passenger carrying service, resulting in exposure of the public to a lower level of safety and the need for expensive retrofit of the fleet.[384]

The report also questioned FAA's ability to identify unsafe conditions through the use of oversight audits and "spot check compliance" conducted months or years after compliance findings had been made. "The likelihood of finding the non-compliant or unsafe features using post certification audits is low," the report warned, "resulting in a lower level of safety than required by the regulations that brought us today's high safety level."[385]

The union representatives sent the report to Dorenda Baker, then-Director of the FAA's Aircraft Certification Service, with a cover letter that explained:

> Unions remain concerned that the current AIR approach to delegation, as well as the AIR Transformation concept, has some fundamental flaws due to a lack of data substantiating the arguments for changes in the FAA's certification process. Unions are concerned that deficiencies in the current and planned organization have a high likelihood of reducing safety.[386]

Specialists (PASS) and the American Federation of State, County & Municipal Employees (AFSCME), February 6, 2017. (On file with the Committee).

[383] Ibid.

[384] Ibid.

[385] Ibid.

[386] Letter from the National Air Traffic Controllers Association (NATCA), the Professional Aviation Safety Specialists (PASS) and the American Federation of State, County & Municipal Employees (AFSCME) to Ms. Dorenda Baker, Director, Aircraft Certification Service, Federal Aviation Administration, regarding "Union Dissenting Opinion report," undated. (On file with the Committee).

In March 2019, as directed by the FAA Reauthorization Act of 2018 (Act), FAA established an ODA Office within its Aviation Safety Organization to lead efforts to improve ODA program performance, standardize application of policy, and ensure consistency in delegation decisions.[387] In addition, FAA initiated an expert panel of ODA holders, aviation manufacturers, safety experts, and FAA labor organizations as directed by the Act to survey existing ODAs and make recommendations to enhance the oversight process and to improve ODA program effectiveness.[388]

Boeing Aviation Safety Oversight Office Concerns and Issues

The FAA's staffing challenges persisted even as delegation authority to ODA holders expanded. These challenges were particularly evident in the FAA's largest ODA oversight office, which is dedicated to overseeing Boeing. In October 2019, the Joint Authorities Technical Review (JATR) commissioned by the FAA to review the 737 MAX certification process reported that the Seattle-based Boeing Aviation Safety Oversight Office (BASOO), under the AIR Systems Oversight Division, was comprised of 45 FAA employees, including 24 total engineers, only 6 of whom were senior engineers, who oversaw the 1,500 Boeing-designated ODA unit members, or authorized representatives.[389] The DOT OIG, which released a report on the 737 MAX in June 2020, cited slightly different numbers regarding the BASOO's staffing levels. It said the BASOO was comprised of 42 FAA employees overseeing approximately 1,500 Boeing-designated ODA representatives that "includes 23 engineers who perform both certification work as well as oversight, 3 inspectors that perform oversight, and additional project manager engineers and support staff."[390]

Regardless of the specific numbers of BASOO staff, the FAA appears to lack the staffing levels required to provide effective and comprehensive oversight of the certification of safety-critical and other components that they have been tasked with overseeing. In recognition of the disparity between the number of FAA BASOO staff and Boeing ODA unit members, JATR said that:

- "The allocated staffing levels of 24 BASOO engineers may not be sufficient to carry out the work associated with retained items and with the conduct of oversight duties."[391]

- "There may be a lack of capacity and depth of experience of BASOO engineering members to approve and make findings of compliance for retained items."[392]

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[387] See FAA Reauthorization Act of 2018, Sec. 212, accessed here: https://www.congress.gov/115/plaws/publ254/PLAW-115publ254.pdf and FAA Response to Questions for the Record submitted by Chairman DeFazio in reference to the Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p. 243, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[388] Ibid.

[389] "Boeing 737 MAX Flight Control System: Observations, Findings, and Recommendations," Joint Authorities Technical Review (JATR), October 11, 2019, p. 27, (Hereafter referred to as "JATR Report"), accessed here: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[390] DOT OIG Report No. AV2020037, p. 3.

[391] JATR Report, p. 27.

[392] Ibid.

- "Depending on the number of entry-level engineers in the BASOO, there could be an imbalance of working-level engineers in relation to the number of senior engineers reasonably expected to be required given the complexity of work by Boeing."[393]

- "The BASOO may not be sufficiently staffed to review all the Boeing programs (737, 747, 767, 777, and 787). There are two technical staff assigned per Boeing program. Some of the technical staff are new engineers with limited airworthiness experience."[394]

- "BASOO engineers [reviewing the 737 MAX] may not have had the technical insight, due to lack of involvement, to assess compliance."[395]

- "The FAA extensively delegated compliance findings on the B737-8 MAX project to the Boeing ODA. Safety critical areas, including system safety documents related to MCAS, were initially retained by the FAA and then delegated to the Boeing ODA."[396]

- "The FAA initially delegated acceptance of approximately 40% of the B737 MAX project's certification plans to the Boeing ODA. Additional certification plans that were originally retained for acceptance by the FAA were later delegated to the Boeing ODA as the certification project progressed. While the JATR team did not conduct an exhaustive review of other ODAs, the team observed that delegating the acceptance of certification plans does not appear to be a widespread practice for the FAA."[397]

- "The FAA should identify and implement procedures for increased direct FAA involvement in safety critical areas of ODA certification projects."[398]

The JATR's key findings mirror many of the Committee's own findings regarding weaknesses in the BASOO's ability to provide adequate oversight of Boeing and gaps in its monitoring of certification activities at Boeing that contributed to safety issues on the 737 MAX aircraft.

As a result of the inadequate number of FAA staff involved, the 737 MAX certification process was extensively delegated to Boeing. This, combined with poor internal FAA communication practices, meant that FAA specialists were not sufficiently aware of safety-critical issues, including many system safety documents related to MCAS. In its report, JATR said that FAA was unable to independently assess the adequacy of Boeing's exercise of its ODA with respect to MCAS, which was a new and novel feature that should have been closely scrutinized.[399] Had FAA

[393] Ibid.
[394] Ibid.
[395] Ibid., p. 28.
[396] Ibid., p. 26.
[397] Ibid.
[398] Ibid.
[399] Ibid., pp. VII and 13-14.

technical staff been fully aware of the details of MCAS, they would have likely identified the potential for the system to overpower other flight controls, which was a major contributing factor leading to the two MAX crashes.[400]

In addition, organizational and operational issues further precluded the BASOO's ability to fully understand the scale, scope, and complexity of work that had been delegated to Boeing. For example, JATR found that Boeing internal procedural layers hindered ARs from directly communicating with BASOO staff. Instead, ARs were allowed to contact the BASOO for technical-only communication to better understand a documented FAA method of compliance, which JATR said prevented the "free communication of issues/concerns to the FAA."[401]

Conflicts of Interest

Authorized representatives (ARs) play a critical role in helping to oversee aircraft and aviation product manufacturers for the FAA under the ODA program. Within the aviation industry, ARs have been described as the eyes and ears of the FAA. However, while acting on behalf of the FAA, ARs are still employees of the organization for which they work, receiving their salary, benefits, and supervision from the entities the FAA is responsible for overseeing. This creates inherent conflicts-of-interest for the ARs and places them at risk of experiencing undue influence from their supervisors or other company officials. In the case of the 737 MAX, the Committee's investigation revealed that on several occasions involving separate incidents, multiple Boeing-designated ARs failed to properly inform the FAA of critical information that would have enhanced the FAA's knowledge of key issues and may have altered their certification decisions. In these instances, the ARs exhibited a too-narrow view of compliance requirements that had profound safety implications.

In establishing the ODA program, the FAA anticipated that a significant number of individual designees who worked for larger organizations such as Boeing would become members of an ODA unit and give up their individual designee status.[402] This represented a key change to the FAA delegation structure. Prior to the establishment of the ODA program, FAA used "designated engineering representatives" (DERs)—private individuals appointed by the FAA who acted on its behalf either as company employees or as independent consultants who may have worked for any client—in performing examinations, inspections, and tests in support of airplane certifications.[403] The DERs who were subsumed into the ODA program faced a significantly altered organizational and communications structure.[404] DERs regularly coordinate with an FAA point-of-contact who provides oversight of the designee's activities.[405] However, under the ODA program, FAA designates an ODA Holder to act as its representative and allows ODA Holders that have had significant experience as a delegated organization to appoint ODA unit members with a minimum

[400] Ibid., pp. 13-14.
[401] Ibid., pp. 28-29.
[402] "Establishment of ODA Program," 70 FR 59931.
[403] See 14 CFR Part 183.
[404] Designated Engineering Representatives (DER), Federal Aviation Administration, https://www.faa.gov/other_visit/aviation_industry/designees_delegations/individual_designees/der/
[405] In addition to designated engineering representatives, FAA also uses individual designees in roles such as pilot examiners, mechanic examiners, and training center evaluators. For additional information, see "Individual Designees," Federal Aviation Administration, accessed here: https://www.faa.gov/other_visit/aviation_industry/designees_delegations/individual_designees

level of FAA involvement.[406] In the case of Boeing, because of its significant experience as a delegated organization, it appoints and manages the ODA unit comprising its cadre of approximately 1,500 ARs.

This fundamental change was partly intended to help the FAA more effectively manage its oversight resources by limiting the number of inquiries FAA technical experts were receiving from Boeing ARs, for instance.[407] Under the new ODA program, Boeing management and AR Advisors serve as a buffer between the ARs and FAA technical experts to help funnel information regarding certification issues to the FAA in a more effective and efficient manner.

While this change relieved FAA of an administrative burden, it limited the interactions between ARs and FAA staff, which as the JATR report noted, prevented the free communication of issues and concerns.[408] As a result, these procedural changes have had the unintended and deleterious effect of hindering the FAA's oversight of Boeing and may have undermined the FAA's ability to be more fully aware of safety issues and concerns that Boeing ARs may have had regarding the 737 MAX. The JATR report recommended that the FAA review whether engineering unit members or ARs "are working without any undue pressure when they are making decisions on behalf of the FAA. This review should include ensuring the [engineering unit members] have open lines of communication to FAA certification engineers without fear of punitive action or process violation."[409]

Anonymous FAA Employee
FAA Safety Culture Assessment
(Draft) February 28, 2020

"IT FEELS LIKE WE ARE SHOWING UP TO A KNIFE FIGHT WITH NERF WEAPONS. IT IS A CHALLENGE TO BE AN EQUAL MATCH WITH BOEING IN THE MEETINGS/CONVERSATIONS."

To its credit, even before that recommendation was made, the FAA's Aviation Safety Organization (AVS) had initiated a large scale "safety culture survey" that was conducted from October 2019 to February 2020. The survey was conducted by The MITRE Corporation[410] and included all 7,147 AVS members, but only 25 percent, or 1,814 individuals, responded.[411] Still, the survey was comprehensive, including 17 interviews with AVS executives and labor leaders and 25 separate focus groups in six separate cities, including Atlanta, Dallas, Seattle, New York, Boston, and Washington, D.C.[412] On the positive side, 71 percent believe their front-line manager supports safety and 69 percent agreed that they are comfortable reporting safety issues/concerns.[413]

406 "Establishment of ODA Program," 70 FR 59931.
407 Ibid.
408 JATR Report, pp. 28-29.
409 Ibid., p. 26.
410 The MITRE Corporation is an independent, non-profit organization that operates multiple federally-funded research and development centers, including the Center for Advanced Aviation Systems Development sponsored by the FAA. "Center for Advanced Aviation System Development," The MITRE Corporation, accessed here: https://www.mitre.org/sites/default/files/publications/caasd-03-2015.pdf
411 FAA Safety Culture Survey.
412 Ibid.
413 Ibid.

However, many of the other survey statistics were disheartening. A full 56 percent of those who responded in the Aircraft Certification Service (AIR) believed "external pressures (e.g., industry) is perceived to get in the way of safety decisions."[414] Within AVS overall, 52 percent did not believe they had enough resources and manpower dedicated to safety, 49 percent believed that safety concerns/incidents will not be addressed so they don't report them, and 43 percent do not believe the FAA appropriately delegates certification activities to organizational and individual designees.[415]

The gist of many of the anonymous responses to the survey questions mimicked what the Committee has heard from numerous whistleblowers over the past 18 months. Among the responses listed in the survey report:

- "It feels like we are showing up to a knife fight with Nerf weapons. It is a challenge to be an equal match with Boeing in the meetings/conversations."[416]
- "They [industry] just keep going up the chain until they get the answers they want."[417]
- "There is no respect for an expert culture that has existed through years of experience. There is no acknowledgement of recommendations made by experts or an explanation about why a different decision was made."[418]
- "There is a fallout of us not being able to do our job. Accidents happen and people get killed."[419]
- "It is common for people to be selected based on managerial skills only regardless of their technical expertise…they don't understand the true risks of the decisions they are making; they are making decisions that they don't have a clue about."[420]
- "There is the perception that technical skills don't matter for managers and they are selected based on their ability to be molded and compliant with upper management's direction."[421]

Further, the adoption of an ODA organizational structure exposed Boeing-appointed ARs to greater risks of undue influence from managers. For example, the JATR reported signs of undue pressure on ARs who perform delegated functions "which may be attributed to conflicting priorities and an environment that does not support FAA requirements."[422] This is consistent with Boeing's own internal survey, conducted in 2016, at the height of the 737 MAX's certification activities and

[414] Ibid.
[415] Ibid.
[416] Ibid.
[417] Ibid.
[418] Ibid.
[419] Ibid.
[420] Ibid.
[421] Ibid.
[422] JATR Report, p. 28.

provided to the Committee from a whistleblower, which found that 39 percent of Boeing ARs that responded perceived potential "undue pressure" and 29 percent were concerned about consequences if they reported potential undue pressure.[423] Both Michael Teal, the former Chief Project Engineer on the 737 MAX program, and Keith Leverkuhn, the former Program Manager of the 737 MAX program, acknowledged in transcribed interviews with Committee staff that they were aware of this internal Boeing survey, but dismissed undue pressure as a significant issue.[424]

Moreover, some FAA officials believe the new ODA system limits the information they receive in negative ways and that they are not always provided with a clear or complete view of issues that could inform and potentially alter their position on certification related issues. According to a story in *The Seattle Times*, a former Boeing aviation-safety engineer who worked as a designated engineering representative under the old designee oversight system and as an AR under the newer system, indicated that there was a dramatic difference between the implied obligations at the core of each system. Under the old system, this engineer said "we knew we'd lose our livelihood if we didn't maintain the integrity of making decisions the way the FAA would do it. That check is no longer there."[425]

Similarly, the Committee found in its investigation that the FAA was not able to check key decisions because ARs never raised issues with the FAA that arguably should have been communicated to the regulatory body charged with overseeing Boeing's work. If these issues had been raised, they may have impacted the FAA's certification decisions regarding the 737 MAX and ultimately improved the safety of the airplane. The Committee's investigation revealed that, in multiple incidents related to the development and certification of the 737 MAX, the Boeing ARs that were supposed to serve as the eyes and ears of the FAA on the ground at Boeing, instead left the FAA largely in the dark about issues that impacted certification, conformity and safety-related matters. These include the following examples which are described in greater detail in the "Maneuvering Characteristics Augmentation System (MCAS)" and "AOA Disagree Alert" sections of this report:

- **MCAS Description** – In 2013, a Boeing AR approved Boeing's actions to describe MCAS externally as an addition to the "speed trim" system as opposed to a "new function" due to Boeing's fears that, "If we emphasize MCAS is a new function there may be a greater certification and training impact."[426]

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[423] "Undue Pressure: Key Learnings and Next Steps," Boeing Commercial Airplanes (BCA), November 2016, pp. 144-151, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf.

[424] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020; and Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020.

[425] Dominic Gates and Mike Baker, "Engineers say Boeing pushed to limit safety testing in race to certify planes, including 737 MAX," Seattle Times, May 5, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/engineers-say-boeing-pushed-to-limit-safety-testing-in-race-to-certify-planes-including-737-max

[426] Internal Boeing email, "PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," Sent: June 7, 2013, 9:10 PM, accessed at p. 93 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf. This issue is discussed in more depth in the *MCAS section*. However, in a letter to the Committee on September 3, 2020, Boeing's Chief Counsel for Regulatory and Legislative Affairs, wrote that the 2013 meeting about MCAS showed that the Boeing participants agreed "'on keeping MCAS nomenclature.'" "The item was then closed," he wrote. "In other words, after reviewing the issue, the team recommended, and their manager agreed, to continue to refer to MCAS

- **MCAS Repetitive Activation** – In 2016, a Boeing AR questioned the ability of MCAS to activate repeatedly and its impact on 737 MAX pilots to counteract MCAS's response after a Boeing test pilot had trouble "trimming" the aircraft due to MCAS's repetitive activation during a test flight.[427] The concern was reviewed by Boeing. It determined there was "No real requirement violation," although Boeing did make minor adjustments to MCAS in response. The AR's concerns were never shared with the FAA.[428]

- **MCAS Functional Hazard Assessment** – From 2015 to 2018, multiple Boeing ARs failed to inform the FAA that Boeing had discovered early on in the MAX program that it took one of its own test pilots more than 10 seconds to respond to an uncommanded activation of MCAS in a flight simulator, a condition the pilot found to be "catastrophic[.]"[429] This should have called into question Boeing's assumptions about pilot response times. It did not. Multiple Boeing ARs were aware of this critical Boeing test data and never shared it with the FAA, because there was no specific requirement to do so.

- **AOA Disagree Alert** – In 2017, a Boeing AR failed to inform the FAA that the AOA Disagree Alert feature on a majority of the 737 MAX fleet were inoperative and that Boeing was aware of this condition. Moreover, Boeing continued to manufacture and deliver airplanes with the nonfunctioning alert to customers without informing them or the FAA that the alert was not operating. Although this feature was not a "safety critical" component, it was **still** required to be functional on all 737 MAX delivered aircraft in order to conform to the aircraft's FAA type certification requirements.[430]

These four incidents illustrate an ODA system that failed to inform the FAA of important information the agency should have been made aware of and, in most cases, exposed the flying public to potential safety dangers.

In another case, a Boeing AR raised a concern about the impact of erroneous AOA data on MCAS, but his query was largely dismissed by his Boeing colleagues, and the concern about this issue was not shared with the FAA. While there is no specific requirement for ARs to report concerns to the FAA, their potential to do so was further precluded from being shared with the FAA in the cases cited above when their Boeing colleagues explained away the concerns. If there had been more fluid and frequent communication between Boeing's ARs and FAA officials in the BASOO and other FAA offices overseeing the certification of the 737 MAX, knowledge of these

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by that name." The letter neglected to cite the rest of this record which indicated Boeing would "continue using the acronym MCAS" internally, however, "[e]xternally we would communicate it is an addition to Speed Trim."

[427] Boeing internal email, "Subject: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Monday, June 13, 2016, 6:17 PM, BATES Number TBC-T&I246488 – TBC-T&I246493. (On file with the Committee).

[428] Boeing internal email, "Subject: RE: Discussion of MCAS Characteristics," Wednesday, June 22, 2016 1:59 PM, BATES Number TBC T&I 292457-29258. (On file with the Committee).

[429] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Email from Boeing counsel to T&I Committee Staff, "Subject: proposed email searches," Sent: Monday, February 10, 2020, 10:42 PM. (On file with the Committee).

[430] Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, regarding the mandatory installation of functional AOA Disagree alerts on all Boeing 737 MAX aircraft, July 11, 2019. (On file with the Committee).

issues by the FAA may have dramatically improved safety of the airplane and enhanced FAA's certification scrutiny of the MAX.

Boeing's ARs are supposed to represent the interests of the FAA and not the company. While the FAA can impose consequences on ARs that fail in their duties, the Committee's investigation has shown that in addition to punitive threats, it is critical for the FAA to also establish a structure that emboldens ARs to willingly report issues of concern or worries about technical design shortcomings to the FAA. If there had been a clear communications vehicle for Boeing's ARs who had concerns about the 737 MAX program to go directly to the FAA and they were encouraged to do so, it may have dramatically improved the FAA's oversight of the program and the ultimate safety of the aircraft.

In situations that warrant the revocation of an AR's designee status, the FAA Administrator may remove a designee if the person "has not properly performed [his or her] duties under the designation."[431] Details regarding these removal procedures are laid out in the ODA procedures order.[432] However, designees seldom have their status revoked, which can be a difficult and long process.

In one case, it took more than three years from when the FAA became concerned about the work of a DER in 1997 to when it decided to decline the designee's renewal request, effective January 1, 2001, after the agency found that the designee had exceeded his authorization in approving repairs on an aircraft and performed poor quality work in other instances.[433] In another case, in February 2003, the U.S. Court of Appeals, District of Columbia Circuit, ruled in favor of the FAA three years after the agency's decision to deny a designee's renewal based on actions the designee made to approve engineering data, find compliance with FAA regulations outside his delegated authority, and perform work on aircraft outside the United States without obtaining authorization from the certification office.[434] In a third example, in June 2014, the same court upheld FAA's action 18 months earlier to terminate the appointment of a designated pilot examiner after an FAA investigation found he had given test applicants the answers on tests, accepted incorrect answers, failed to cover mandatory subjects, and failed to test mandatory maneuvers during test rides.[435] Removing designees, as happened in these cases, however, is very rare.

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[431] See 14 CFR 183.15, "Duration of certificates," Federal Aviation Administration, accessed here: https://www.govinfo.gov/app/details/CFR-2003-title14-vol3/CFR-2003-title14-vol3-sec183-15

[432] "Organization Designation Authorization Procedures," National Policy, Order 8100.15, Federal Aviation Administration (FAA), Department of Transportation (DOT), June 15, 2018, accessed here: https://rgl.faa.gov/regulatory_and_guidance_library/rgorders.nsf/0/f8e0e1795804a25086257b6d005db348/$FILE/8100.15B_CHG3_Incorporated.pdf

[433] Randy Steenholdt, Petitioner, vs. Federal Aviation Administration, Respondent. No. 01-1331, 314 F. 3d 633, United States Court of Appeals, District of Columbia, Circuit Court, Argued: October 7, 2002, Decided: January 10, 2003, accessed here: https://scholar.google.com/scholar_case?case=3215188119166900298&q=Randy+Steenholdt,+Petitioner,+vs.+Federal+Aviation+Administration,+Respondent.+No.+01-1331,+&hl=en&as_sdt=20006

[434] Carlos Lopez, Petitioner, vs. Federal Aviation Administration, Respondent. No. 01-1427, 318 F. 3d 242, United States Court of Appeals, District of Columbia, Circuit Court, February 11, 2003, Rehearing Denied March 5, 2003, accessed here: https://scholar.google.com/scholar_case?case=10150991282292631381&q=%22carlos+lopez%22+AND+FAA&hl=en&as_sdt=20006

[435] Joseph F. Sheble, III, Petitioner v. Michael P. Huerta, et al., Respondents. No. 13-1136, 755 F. 3d 954, United States Court of Appeals, District of Columbia, Circuit Court, Argued: January 9, 2014, Decided: June 24, 2014, accessed here:

Taking steps to better train ARs, significantly enhance FAA oversight of Boeing's ODA designees, and enable the FAA to take swift action when it is clear an AR is serving the interests of the ODA Holder and not the interests of the FAA would help dramatically improve oversight of the ODA program and the safety of the flying public. In addition, avenues for ARs to share concerns they may have about technical design features or the path of a specific aircraft program must be expanded and improved to help encourage ARs to report these issues to the Federal regulatory agency that is tasked with overseeing Boeing and ensuring that the aircraft it certifies are safe.

Certification Process Affected by Mismanaged Communications

The Committee's investigation found that fragmented communication between Boeing and the FAA, as well as among FAA's own internal offices, hindered the exchange of information. In July 2017, for instance, a member of the FAA's BASOO sent an email to colleagues in the FAA's Aircraft Evaluation Group (AEG) that referenced an Airplane Assessment Report (AAR) on the 737 MAX. The author of the email wrote, "It was the intent to coordinate all changes to the approved validation plan task list with the FAA-AEG office, however due to schedule/availability disconnects a small number of changes were not formally coordinated."[436] In some cases, coordination was not simply delayed but never actually occurred. This lack of clear and consistent coordination on key issues regarding the certification of the 737 MAX had significant consequences depriving essential FAA experts of information that may have altered some of their decisions regarding the certification of the 737 MAX.

Most notably, the certification of MCAS illustrates how fragmented communications resulted in information gaps within the FAA concerning this critical system. These information gaps precluded key FAA employees from developing a full understanding of MCAS, its operational performance characteristics, and the safety risks it presented. Furthermore, Boeing failed to communicate fundamental information to all of the FAA offices that should have been aware of key data related to the certification of the 737 MAX. For example:

- **Aircraft Evaluation Group (AEG)** – The Seattle AEG was responsible for coordinating and managing proposed pilot training requirements on the 737 MAX.[437] Boeing requested—and the AEG permitted—the removal of reference to MCAS from Boeing's Flight Crew Operations Manual (FCOM) at the time Boeing was re-designing the system to operate with greater authority.[438] However, the AEG staff remained unaware of the MCAS re-design until **after** the crash of Lion Air flight 610.

https://scholar.google.com/scholar_case?case=7646547281908654251&q=sheble+vs.+faa+and+huerta&hl=en&as_sdt=20006

[436] FAA internal email, "Subject: RE: 737-8 ETOPS Airplane Assessment Report (AAR)," July 12, 2017, 9:38 a.m., BATES Number, FAA-T&I 00041270-41271 (On file with the Committee).

[437] The AEG is part of the Aircraft Evaluation Division which helps to coordinate and assist with aircraft certification and continued airworthiness programs. The AEG also plays a pivotal role establishing and managing the Flight Standardization Board that determines requirements for pilot type ratings, develops training objectives, and conducts initial training for both the manufacturer's pilots and FAA inspectors to ensure initial competency of flight crews. See "Aircraft Evaluation Division (AED)," Federal Aviation Administration, accessed here: https://www.faa.gov/about/office_org/field_offices/aed/ and "Flight Standardization Board (FSB)," Federal Aviation Administration, accessed here: https://www.faa.gov/aircraft/air_cert/airworthiness_certification/fsb

[438] The AEG uses the FSB report as the basis for the approval of pilot training and qualification necessary for the operation of aircraft. See "Subject: Guidance for Conducting and Use of Flight Standardization Board Evaluations,"

- **Boeing Aviation Safety Oversight Office (BASOO)** – The BASOO had delegated to Boeing the certification actions that pertained to MCAS; however, Boeing failed to update the affected certification plans and notify the BASOO when it re-designed MCAS in March 2016.[439] As a result, the BASOO employees that should have been informed of this significant change by Boeing did not learn of it until **after** the Lion Air crash.[440]

- **Aircraft Certification Office (ACO)** – FAA test pilots in the Seattle ACO supported the 737 MAX's certification by ensuring through test flight procedures that the airplane complied with regulations concerning its handling. The ACO worked with Boeing's test pilots to develop flight test certification plans and approved reports that documented the performance of the 737 MAX during flight tests.[441] ACO staff were aware of the MCAS re-design that occurred in 2016 because it affected tests that they participated in, but they failed to share information about the re-design of MCAS with other FAA offices.[442]

Collectively, the MCAS re-design illustrates a situation where knowledge of the change existed in at least one FAA office but not others, and where effective information exchanges between offices did not occur. Boeing's failure to more fully communicate information about the system's re-design compounded the problem with siloed information. As the JATR observed, fragmented communications made it more challenging for the FAA to recognize the impacts and implications that MCAS posed to the airplane and to 737 MAX pilots.[443] Had the information pertaining to the MCAS re-design been shared with a greater number of FAA experts, it would have likely impacted the decisions they made regarding certification of the MAX.

While FAA's organizational entities are responsible for performing their assigned roles and not every FAA official can know of everything, the MCAS re-design example shows that FAA officials could have and should have been more cognizant of critical issues affecting the certification of the 737 MAX. The lack of a centralized FAA authority overseeing the entire 737 MAX certification process contributed to the communication lapses that ultimately affected safety and played a significant role in the 737 MAX crashes.

Advisory Circular, AC No: 120-53B, Federal Aviation Administration (FAA), Department of Transportation (DOT), October 24, 2016, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-53B_Chg_1.pdf. The AEG does not technically approve the FCOM; however, it is customarily involved in its review as the FCOM may be referenced in training materials. As related to the AEG permitting the removal of references to MCAS in the FCOM, see: Email from 737 Chief Technical Pilot to FAA, "Subject: MCAS lives in both FCCs," Sent: Wednesday, March 30, 2016, 11:16:45. (On file with the Committee).

[439] JATR Report, p. 24.

[440] DOT OIG Report No. AV2020037, p. 32.

[441] See Flight Test Certification Report, Airplane Model 737-8, Title: 737-8 Control System Malfunctions, Boeing Test & Evaluation, Seattle, Washington, August 21, 2017, TBC-T&I056097, 056102-056104, 056107-056108, and 056123.

[442] "Response to Question 7 and Related Questions," (Informally referred to as the "Boeing MCAS Narrative"), The Boeing Company, response to the Committee on Transportation and Infrastructure, BATES Number TBC T&I 372821-372832 at TBC T&I 372825 (On file with the Committee), and Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.

[443] JATR, p. 13.

This negligent breakdown in communications did not start and stop at the FAA's door, however. One Boeing AR graphically described disjointed communications and varied interpretations of FAA policies and procedures among different Boeing technical groups involved in the 737 MAX program. In a February 2016 email, this AR included references to Type Inspection Authorization (TIA) procedures used to authorize "official conformity, airworthiness inspections, and flight tests necessary to fulfill certain requirements" for aircraft type certifications.[444] The AR observed that some Boeing groups provided great detail on their plans for progressing through testing to eventual certification while other groups provided no detail at all.[445] As a result of these differences, the FAA lacked sufficient basis for understanding what ARs were approving and had an overall incomplete picture of key certification plans. "Thus there is no confidence that the FAA is understanding what they are accepting (or rejecting)," the AR wrote. "No confidence in how to interpret what is acceptable and not acceptable for post TIA configuration changes and thus no confidence that ARs are doing the right thing in 'concurring.'" The AR described the situation as a "crisis in confidence," clearly expressing worry about what ARs were agreeing to or concurring with in regard to Boeing's actions.[446]

Boeing Authorized Representative (AR) Internal Email February 25, 2016

"[T]HERE IS NO CONFIDENCE THAT THE FAA IS UNDERSTANDING WHAT THEY ARE ACCEPTING (OR REJECTING)."

History of FAA Bias Favoring Boeing

Aside from issues specifically revolving around the ODA system, the Committee has discovered multiple cases where FAA's senior leaders have made certification decisions that were biased towards Boeing's own business interests and that undermined the safety concerns of the FAA's own experts. The FAA's own internal survey of Aviation Safety (AVS) staff documented widespread and similar concerns. According to the survey results, "Many believe that AVS senior leaders are overly concerned with achieving the business-oriented outcomes of industry stakeholders and are not held accountable for safety-related decisions."[447] It also found that, "Employees and managers reported that external pressure from industry is strong and is impacting the AVS safety culture."[448] The Committee's own investigation was made aware of several examples of such decisions by FAA that illustrate this bias. These examples go beyond the 737 MAX program and have affected other Boeing programs as well.

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[444] See "Type Inspection Authorization, FAA Form 8110-1," Federal Aviation Administration (FAA), Department of Transportation (DOT), accessed here: https://www.faa.gov/other_visit/aviation_industry/designees_delegations/resources/forms/media/FAA_Form_8110-1.pdf. The TIA is an internal FAA document that authorizes the ACO employees to begin the test program, usually the flight test portion. Official FAA flight testing begins only after the FAA issues a TIA. However, the applicant conducts the tests and inspections to demonstrate that the test article to be submitted for FAA certification ground and flight tests meets the minimum requirements for quality, conforms to the design data, and is safe for the planned tests.
[445] Internal Boeing email, "Subject: RE: For 2pm," Sent: February 25, 2016, 7:57:28 AM, accessed at p. 89 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[446] Ibid.
[447] FAA Safety Culture Survey.
[448] Ibid.

787 Dreamliner Lithium Batteries

In 2011, Boeing's 787 Dreamliner was certified by the FAA[449] and entered commercial revenue service that same year.[450] The airplane incorporated many advanced technologies such as fuel-efficient engines, a body fabricated primarily from composite materials, and lithium batteries in its electrical system.[451] However, these lithium batteries had a history of being significantly more susceptible to fire than other types of batteries.[452] The risk of transporting lithium batteries on cargo airplanes was known prior to the 787 Dreamliner's certification. A 2011 FAA analysis that examined five cargo fires on U.S. registered airplanes from 1973 through 2010 predicted that as many as 4 to 5 additional cargo fires involving lithium batteries could occur by 2020.[453] Separately, in 2006, a lithium battery exploded at the Tucson, Arizona, site of Securaplane Technologies, Inc., burning the facility to the ground.[454] Securaplane is one of the Boeing suppliers of the charging system for the Dreamliner's lithium batteries—the system that was being tested when the battery fire occurred.[455]

To ensure the safety of the 787 Dreamliner, its passengers, and crew, Boeing and the FAA established design protections to prevent the batteries from overcharging and to reduce the risk of fire.[456] Further, in 2007 the FAA set nine "special conditions" for the containment or venting of any hazardous materials that Boeing was required to meet related to the installation of lithium batteries on the 787 Dreamliner because regulations concerning use of lithium batteries did not exist.[457] Despite that, in the first few weeks of January 2013, two lithium battery incidents involving fire and smoke from the batteries occurred on separate 787 Dreamliners.[458] This led the FAA to ground all 787 Dreamliner airplanes on January 16, 2013.[459]

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[449] "Boeing 787 Dreamliner Receives FAA, EASA Certification," Boeing Press Release, August 26, 2011, accessed here: https://boeing.mediaroom.com/2011-08-26-Boeing-787-Dreamliner-Receives-FAA-EASA-Certification

[450] "Boeing, ANA Complete Contractual Delivery of First 787 Dreamliner," Boeing Press Release, September 25, 2011, accessed here: https://boeing.mediaroom.com/2011-09-25-Boeing-ANA-Complete-Contractual-Delivery-of-First-787-Dreamliner

[451] Lithium-ion batteries weigh less than the nickel-cadmium batteries that had been traditionally used on board airplanes. Batteries on airplanes are used pre-flight for purposes such as powering the flight control computer and starting the engines. See Thom Patterson, "Dreamliner battery probe ends: 8 questions and answers," *CNN*, December 12, 2014, accessed here: https://www.cnn.com/travel/article/boeing-787-dreamliner-investigation-report/index.html

[452] Alwyn Scott and Mari Saito, "Boeing 787 battery woes put FAA approval under scrutiny," *Reuters*, January 22, 2013, accessed here: https://www.reuters.com/article/us-boeing-787-faa/insight-boeing-787-battery-woes-put-faa-approval-under-scrutiny-idUSBRE90M04620130123

[453] "Freighter Airplane Cargo Fire Risk Model," DOT/FAA/AR-11/18, Federal Aviation Administration (FAA), Department of Transportation (DOT), September 2011, accessed here: https://www.fire.tc.faa.gov/pdf/11-18.pdf; and "2011 FAA Fire Safety Highlights," Federal Aviation Administration, Undated, accessed here: https://www.fire.tc.faa.gov/pdf/2011Highlights.pdf

[454] Bob Brewin, "A 2006 battery fire destroyed Boeing 787 supplier's facility," *Nextgov*, January 22, 2013, accessed here: https://www.nextgov.com/emerging-tech/2013/01/2006-battery-fire-destroyed-boeing-787-suppliers-facility/60809

[455] Carli Brosseau, "NTSB to test 787's charger system here: Its maker, Securaplane, and US officials meet today in safety inquiry," *Arizona Daily Star*, January 22, 2013, accessed here: https://tucson.com/business/local/ntsb-to-test-s-charger-system-here/article_37204df6-1064-59d5-9855-651a4b9d7e1b.html

[456] Alwyn Scott and Mari Saito, "Boeing 787 battery woes put FAA approval under scrutiny," *Reuters*, January 22, 2013, accessed here: https://www.reuters.com/article/us-boeing-787-faa/insight-boeing-787-battery-woes-put-faa-approval-under-scrutiny-idUSBRE90M04620130123

[457] Ibid.

[458] "FAA Statement on Grounding of 787 Dreamliner Fleet," Press Release, Federal Aviation Administration, January 16, 2013, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=14233

[459] Ibid.

"We were focused on the hazards of the battery," explained Ali Bahrami, then Director of the FAA's Transport Airplanes Directorate that was in charge of the 787 Dreamliner's certification, at an April 2013 National Transportation Safety Board (NTSB) hearing describing how the batteries were approved for use on the then-grounded airplane. "We knew the hazards were always there. The awareness was always there. We did the best we could under the circumstances, and the knowledge that existed then, to come up with standards that address the requirements for this particular battery."[460] At the same hearing, Mike Sinnett, Boeing's chief engineer on the 787 Dreamliner, said that the airplane's certification by the FAA took 200,000 hours and was the most "extensive in our company's history," adding that the battery's certification was "very rigorous and subject to close scrutiny by the FAA."[461]

But in November 2014, the NTSB released the results of its final report on the 787 Dreamliner's lithium battery fires and indicated numerous problems with Boeing's design and testing and with FAA's oversight of Boeing.[462] Problems that the NTSB identified included "insufficient guidance for manufacturers to use in determining and justifying key assumptions in safety assessments," and insufficient guidance for FAA "certification engineers to use during the type certification process to ensure compliance with applicable" FAA requirements.[463] The NTSB also identified inadequate FAA oversight, a failure by both FAA and Boeing to identify critical deficiencies, and flawed assumptions by Boeing.[464] These same problems were plainly evident on the development and certification of the 737 MAX as well.

The battery issues and subsequent grounding of the 787 Dreamliner may have been avoided had FAA officials acted on the recommendation of one of its own engineers who reviewed the design of the batteries as part of the airplane's certification. In testimony to the Committee in December 2019, G. Michael Collins, a former FAA engineer with three decades of experience at the agency, who had knowledge of the Dreamliner's battery issues, said that during the airplane's certification process, an FAA engineer had proposed the use of a steel container to enclose the lithium batteries and prevent an uncontrolled fire should the batteries ignite.[465] However, Mr. Collins said FAA managers did not support the engineer's proposal and left the certification decision about the batteries' installation to be made by the Boeing ODA instead. The ODA ultimately decided that installing the batteries free of an enclosure would comply with the special conditions that had been established for use of lithium batteries. It was only after the grounding of the Dreamliner as a result of the extremely dangerous battery fires that the FAA mandated use of a steel container vented to the outside of the airplane—as originally recommended by its own engineer.[466]

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[460] Matthew L. Wald and Jad Mouawad, "Boeing Acknowledges Tests Underestimated 787 Battery Risks," *New York Times*, April 23, 2013, accessed here: https://www.nytimes.com/2013/04/24/business/safety-board-examines-787-battery-approval.html
[461] Ibid.
[462] "Aircraft Incident Report: Auxiliary Power Unit Battery Fire, Japan Airlines Boeing 787-8, JA829J," Boston Massachusetts, January 7, 2013, NTSB/AIR-14/01, National Transportation Safety Board, November 21, 2014, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/AIR1401.pdf
[463] Ibid. p. ix.
[464] Ibid. pp. viii, x, and 70.
[465] Prepared Statement of G. Michael Collins, Former Aerospace Engineer, Federal Aviation Administration, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification
[466] Ibid.

In the case involving new lithium batteries on the 787 Dreamliner, as well as in the case of MCAS on the 737 MAX, the FAA and Boeing downplayed, ignored, or did not adequately understand or address the safety issues presented by these new features during the development and certification of those airplanes. Neither the lithium batteries nor MCAS were considered 'safety critical' systems and yet they led to safety incidents on the 787 Dreamliner and two fatal accidents of the 737 MAX aircraft. As reported by *CNN* in its analysis of NTSB's November 2014 report on the 787 Dreamliner battery incidents, "any new piece of equipment can pose dangerous problems, even a noncritical piece of equipment like batteries."[467] The combination of problems, identified by the NTSB in the 787 Dreamliner battery incidents and the issues identified by the Committee's investigation of the 737 MAX crashes, points to the need for fundamental changes to strengthen FAA's oversight of manufacturers so that critical safety deficiencies can be better identified and flawed assumptions biased toward industry interests can be avoided.

Anonymous FAA Employee
FAA Safety Culture Assessment Report (Draft) February 28, 2020

"THERE IS NO RESPECT FOR AN EXPERT CULTURE THAT HAS EXISTED THROUGH YEARS OF EXPERIENCE. THERE IS NO ACKNOWLEDGEMENT OF RECOMMENDATIONS MADE BY EXPERTS OR AN EXPLANATION ABOUT WHY A DIFFERENT DECISION WAS MADE."

737 MAX Rudder Cable

During the design of the 737 MAX, FAA bias toward Boeing was also shown in the handling of technical concerns regarding the airplane's rudder cable design. Federal regulation requires design precautions be taken to minimize risks posed by uncontained engine failures, events in which fragments from the damaged engine can penetrate parts of the airplane and cause additional damage to its fuselage, fuel tanks, and other systems.[468] These requirements are based on a history of related incidents and the resultant inability of pilots to safely control the impacted airplanes. For example, on July 18, 1989, a McDonnell Douglas DC-10 operating United Airlines flight 232, en-route from Denver to Chicago, attempted to make an emergency landing in Sioux City, Iowa, after the airplane suffered an uncontained failure of its tail engine in which engine fragments severed the hydraulic lines used to move the rudder and other control surfaces on the plane's aft stabilizer.[469] The flight crew's ability to control the airplane was severely impaired as a result of this damage, and it crash landed at the Sioux City Gateway Airport killing 112 people. Miraculously 184 others survived.[470]

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[467] Thom Patterson, "Dreamliner battery probe ends: 8 questions and answers," *CNN*, December 12, 2014, accessed here: https://www.cnn.com/travel/article/boeing-787-dreamliner-investigation-report/index.html and "NTSB Recommends Process Improvements for Certifying Lithium-ion Batteries as it Concludes its Investigation of the 787 Boston Battery Fire Incident," National Transportation Safety Board (NTSB), December 1, 2014, accessed here: https://www.ntsb.gov/news/press-releases/Pages/PR20141201.aspx

[468] 14 C.F.R. § 25.903(d)(1).

[469] Katie Peikes, "30 Years Since Flight 232 Crash-Landed In Sioux City," *Iowa Public Radio*, July 19, 2019, accessed here: https://www.iowapublicradio.org/post/30-years-flight-232-crash-landed-sioux-city#stream/0

[470] Gary Washburn, "Simulator Pilot Says DC-10 Had No Chance," *Chicago Tribune*, November 1, 1989, accessed here: https://www.chicagotribune.com/news/ct-xpm-1989-11-01-8901270267-story.html

In 1997, mindful of the 1989 crash in which fragments from the DC-10's exploded engine shred the airplane's hydraulic lines and disabled the rudder controls, the FAA issued an Advisory Circular that recommended design precautions be taken to minimize risks posed by uncontained engine failures.[471] These issues were further clarified in the Code of Federal Regulations, which mandated "[d]esign precautions must be taken to minimize the hazards to the airplane in the event of an engine rotor failure or of a fire originating within the engine which burns through the engine case."[472] Further, also in 1997, when FAA was considering the safety of the rudder cable on the 737 NG, it promulgated an issue paper that concluded:

> Boeing should be aware that further increase in thrust, introduction of new engines, or changes to the structure or flight control system will necessitate a review of the FAA position and the requirements for redundancy and separation in the flight control systems. In anticipation of a long life for the new Model 737 derivative airplanes and the potential for changes, in particular growth in engine power or new engines, the FAA believes greater redundancy and separation in the design of the flight control systems in the vicinity of the rotor burst zone should be incorporated, although such improvements are not required at this time. In addition, it should be noted that for future certification programs, a greater level of minimization would be expected for a new type certificated aircraft.[473]

Despite that, three decades after the DC-10 crash, senior FAA management overruled both the professional judgement of a large group of FAA technical specialists and the recommendations of a safety review panel to permit the 737 MAX to be certified despite a design vulnerability that exposed the airplane's rudder cable to damage during an uncontained engine failure.

Chair DeFazio and Subcommittee on Aviation Chair Larsen expressed their ongoing concerns about the 737 rudder cable issue in a November 2019 letter they sent to the FAA.[474] These concerns stemmed from FAA's action in 2016 to offer Boeing a chance to establish compliance with the regulation to minimize the hazards to the airplane from uncontained engine failure **without** implementing a design change. At least six FAA specialists refused to concur with the issue paper that described the proposed method of compliance resulting in the empanelment of an oversight board in accordance with FAA's safety review process.[475]

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[471] "Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure," Advisory Circular 20-128A, Federal Aviation Administration, Department of Transportation, March 25, 1997, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_20-128A.pdf

[472] 14 C.F.R. § 25.903(d)(1) – "Engines," Federal Aviation Administration, Department of Transportation, accessed here: https://www.govinfo.gov/app/details/CFR-2011-title14-vol1/CFR-2011-title14-vol1-sec25-903

[473] "Issue Paper," Project: Boeing Commercial Airplane Group 737-600/-700/-800 AT0328SE-T, Subject: Engine Rotor Non-Containment and Critical Flight Controls, March 21, 1997, accessed at pp. 157-161 at p. 161 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[474] Letter from Chair DeFazio and Subcommittee on Aviation Chair Larsen to FAA Administrator Dickson citing FAA Issue Paper: Engine Rotor Burst and Rudder Mechanical Flight Control Cables, November 7, 2019, accessed here: https://transportation.house.gov/imo/media/doc/DeFazio,%20Larsen%20Letter%20to%20FAA%20re%20rudder%20cables,%20lightning%20covers.pdf

[475] Ibid. See also: "Issue Paper of March 21, 2016, on rudder cable – FAA-DeFazio 28872-28888" in Hearing before the Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October

In his December 2019 testimony to the Committee, Mr. Collins, the former FAA engineer who was one of four members of the oversight board, further described the review process.[476] Due to the technical nature of the issue, Mr. Collins explained that the oversight board convened an expert panel comprised of four additional FAA engineers and two FAA managers to investigate whether the 737 MAX's design was compliant with the requirement to minimize the hazards from an uncontained engine failure.[477]

In January 2017, the expert panel determined that the method of compliance offered by FAA management in its issue paper did **not** meet the minimum level of safety required by the regulations.[478] The oversight board concurred with the panel's recommendation and forwarded the panel's report to FAA's Aircraft Certification Service (AIR) for the responsible manager to decide on the outcome of the issue. Ultimately, the AIR manager responded that the deciding authority had considered the board's recommendations but determined that all rules, orders, and procedures had been followed with regards to the airplane's certification.[479] This effectively closed the issue with FAA finding that the airplane was compliant with the requirement to minimize the risk of uncontained engine failure, despite the fact that a group of at least 18 FAA officials, including 13 FAA technical experts, four FAA managers and one FAA pilot had all recommended otherwise.[480]

FAA management has the right to overrule the Agency's technical experts. This does happen. However, FAA management overruling 18 of its own technical experts without a substantive and persuasive rebuttal to their concerns is extraordinarily unusual and highly troubling.

In his testimony to the Committee, Mr. Collins recounted how during his early years at the FAA, he experienced a much different safety culture where managers and designated engineering representatives worked collaboratively with an applicant to resolve design deficiencies.[481] More recently, according to Mr. Collins, FAA's safety culture has been negatively transformed. Today, FAA's management has permitted manufacturers to produce airplanes that do not comply with safety standards, according to Mr. Collins. This has jeopardized aviation safety and demoralized FAA's critically important technical workforce that has strongly opposed those decisions.[482]

30, 2019, pp. 241 – 257, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[476] Prepared Statement of G. Michael Collins, Former Aerospace Engineer, Federal Aviation Administration, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification; see also "Safety Review Program Findings and Recommendations – FAA-DeFazio 28922-28937" in Hearing before the Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, pp. 258 - 273, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[477] Ibid.

[478] Ibid.

[479] Ibid.

[480] Ibid.

[481] Prepared Statement of G. Michael Collins, Former Aerospace Engineer, Federal Aviation Administration, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification

[482] Ibid.

787 Dreamliner Lightning Protection

In addition to the safety hazard presented by an uncontained engine failure on the 737 MAX, the 787 Dreamliner was exposed to greater risk when FAA management sided with Boeing over the advice of its technical experts in the case of its fuel tank lightning protection.

FAA Employee
Internal FAA Email
June 14, 2019

"THIS IS CLEARLY A CONTENTIOUS ISSUE AND BOEING IS RUSHING THE CERTIFICATION SO THEY CAN DELIVER AIPLANES."

Because the 787 Dreamliner consists of more than 50 percent carbon fiber composites that are not inherently conductive, it is at greater risk to damage from lightning strikes compared to other aircraft.[483] To mitigate this risk, Boeing designed and initially produced aircraft with copper foil on a portion of the wing. The foil served to rapidly dissipate excessive electric current and heat from a lightning strike to help prevent the fuel contained within the airplane's wings from potentially igniting. However, in late 2018, Boeing decided that the foil was not needed and eliminated its use in production.[484]

In particular, as part of its investigation, the Committee learned that Boeing removed the protective foil on an estimated 40 'wing sets' on the 787 Dreamliner **before** seeking or receiving FAA approval.[485] On February 22, 2019, FAA's BASOO formally rejected Boeing's design change based on experts' concerns that removing the copper foil on the wings created a greater risk of fuel tank ignition.[486] However, Boeing appealed this decision. Exactly one week later, on March 1, 2019, FAA management overturned the BASOO's decision and allowed Boeing to continue producing the 787 Dreamliner without the copper foil to the dismay of FAA's technical experts.[487] In short, following Boeing's appeal, the FAA reversed its decision, rejecting the safety concerns of its own technical experts.

The issue, however, continued to concern FAA technical experts even after the FAA's official ruling. As one FAA expert wrote in an email on June 14, 2019, to seven of his colleagues, "This is clearly a contentious issue and Boeing is rushing the certification so they can deliver

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[483] Jennifer Segui, "Protecting Aircraft Composites from Lightning Strike Damage," *COMSOL Blog*, June 11, 2015, accessed here: https://www.comsol.com/blogs/protecting-aircraft-composites-from-lightning-strike-damage

[484] Internal FAA email, "Subject: RE: Cu Foil Removal from 787 composite wings- Making it hard for us to do our job!" Sent: January 31, 2019, 4:03:00 PM (On file with the Committee).

[485] FAA Memorandum, "Subject: Article 65 Difference in Professional Opinion, Removal of lighting protection features (Copper Foil and Dielectric Cap) From 787 Fuel Tanks," April 2, 2019 (On file with the Committee), and Dominic Gates, "FAA engineers objected to Boeing's removal of some 787 lightning protection measures," *The Seattle Times*, December 10, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-engineers-objected-to-boeings-removal-of-some-787-lightning-protection-measures

[486] FAA letter to Boeing, "Subject: The Boeing Company (TBC) Regulatory Administration (RA) Project Number PS16-0765, "Recommend Approval of 787 Fuel Tank Structural Lightning Protection System Safety Assessment," Deliverable Number 4 and Deliverable Number 5 for Certification Plan (CP) Number 20595," Reference 860-19-0120, February 22, 2019, accessed at p. 152 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[487] FAA letter to Boeing, "Subject: BASOO and Organization Management Team (OMT) Response to Boeing Appeal related to Boeing Commercial Airplanes (BCA) Regulatory Administration (RA) Project Number PS16-0765, and 787 Lightning Zone 3 Compliance to Special Condition 25-414-SC," Reference 860-19-0149, March 1, 2019, accessed at p. 157 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

airplanes."[488] In a separate memo to FAA management on June 27, 2019, an FAA employee wrote of his concerns that FAA management was delegating the System Safety Assessment to Boeing simply because the FAA could not "support the airplane delivery schedule."[489] He went on to say, "I do not agree that delivery schedules should influence our safety decisions and areas of safety critical findings, nor is this consistent with our safety principles."[490]

He concluded that he believed the FAA was "allowing Boeing to further erode the level of safety of the airplane without the ability to assess the residual risk."[491] While none of these altered 787 Dreamliner aircraft were delivered to Boeing's customers prior to FAA's approval of the design change, one FAA official involved in this issue told Committee staff that he believed this was a way for Boeing to game the system.[492] By the time Boeing alerted the FAA about the changes, it had proceeded so far into production that it could claim that making a change was untenable in view of a tight delivery schedule and argue that it would lose millions of dollars if it was forced to scrap the wing sets it had already produced. As a result, FAA managers were under tremendous pressure to approve Boeing's design changes, this FAA official observed.[493]

In an interview with Committee staff in December 2019, Ali Bahrami, the FAA's Associate Administrator for Aviation Safety, said he was completely unaware of the 787 Dreamliner lightning protection issues until it was raised with the FAA by the Committee in November 2019.[494] He also suggested that there was nothing wrong with Boeing making these changes prior to FAA approval, but that Boeing was at financial risk if the FAA did not approve of Boeing's redesign.[495] While Mr. Bahrami pointed out that "manufacturers can produce anything they want," he clarified that "they cannot deliver" anything that FAA does not approve.[496] As previously stated however, some FAA officials believed Boeing was betting on the fact that they would be able to persuade FAA management to side with them regarding the removal of the 787's lightning protection features, which they ultimately did.

While issues of "non-concurrence," such as with the 737 MAX's rudder cable and the 787 Dreamliner's lightning protection, do occur, they are relatively infrequent and are often viewed as a last-ditch method of raising safety issues that the FAA's technical staff believe are of significant importance. FAA managers have the right to overrule their technical staff on these and other safety-related matters. However, these instances of FAA technical experts being overruled to allow the production of airplanes that lack arguably important safety features raise serious questions about 1) how FAA manages safety and 2) how powerful corporations such as Boeing exert influence over FAA to act in the company's interests, often at the expense of safety.

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488 Internal FAA Email, "Subject: 787 lightning protection," Sent: Friday, June 14, 2019 7:46 AM. (On file with the Committee).
489 Internal FAA memorandum of non-concurrence regarding lightning protection requirements on the 787 Dreamliner, June 27, 2019. (On file with the Committee).
490 Ibid.
491 Ibid.
492 Confidential conversation between Democratic Committee staff with FAA whistleblower, August 29, 2019.
493 Ibid.
494 Committee staff transcribed interview of Ali Bahrami, FAA Associate Administrator for Aviation Safety, December 5, 2019.
495 Ibid.
496 Ibid.

Reports of undue influence by Boeing continue to emerge, highlighting attempts to thwart potential safety measures, appropriate accountability and effective oversight. According to the DOT OIG, in November 2018 the FAA initiated a formal compliance action against Boeing related to the ODA program shortly after the Lion Air accident, but unrelated to the accident.[497] These actions revolved around "undue pressure" by Boeing on ODA unit members. These incidents in and of themselves are troubling. However, Boeing's response to the FAA raises additional disturbing issues regarding Boeing's efforts to acknowledge and correct its blatant ODA oversight deficiencies. According to the DOT OIG, which recently released a report on the 737 MAX certification efforts that mentioned the FAA's November 2018 compliance action against Boeing:

> In subsequent months, Boeing requested three extensions from FAA before providing its response to the compliance action, including a corrective action plan. FAA did not accept Boeing's response to this compliance action. FAA also issued two separate letters of investigation in June 2019 and March 2020 against Boeing, related to potential undue pressure of unit members. FAA did not accept Boeing's response to the June 2019 letter of investigation and is currently evaluating that letter of investigation and the formal compliance action together. The Agency is still awaiting Boeing's response to the more recent March 2020 letter of investigation.[498]

Effectiveness of Compliance and Enforcement Actions

The FAA's administration of the ODA program rests on its ability to implement compliance and enforcement actions to ensure that designees meet their responsibilities. In June 2015, FAA announced a new enforcement policy with a more collaborative and problem-solving approach called the Compliance Program.[499] As a result of this change, FAA has increasingly used compliance actions, such as counseling or training, rather than enforcement actions, such as civil penalties, to address violations of safety standards.[500] The Government Accountability Office (GAO) recently investigated the changes to these policies and their implications for FAA oversight. The GAO released their evaluation in August 2020 and reported a 90 percent decrease in the number of enforcement actions undertaken by the FAA's Aircraft Certification Office from 2012 to 2019.[501]

While FAA expects that this new approach will allow it to address the root cause of safety standard violations upfront, GAO found that the FAA's tracking of actions is less centralized and

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[497] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Office of Inspector General (OIG), Department of Transportation (DOT), Report No. AV2020037, June 29, 2020, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[498] Ibid.

[499] Initially known as the Compliance Philosophy, FAA renamed this change to its enforcement and compliance policy to the Compliance Program in 2018. See FAA Order 8000.373A, "SUBJ: Federal Aviation Administration Compliance Program," October 31, 2018, accessed here: https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8000.373A.pdf

[500] "Aviation Safety: Actions Needed to Evaluate Changes to FAA's Enforcement Policy on Safety Standards," GAO-20-642, Government Accountability Office (GAO), August 18, 2020, accessed here: https://www.gao.gov/assets/710/708877.pdf

[501] Ibid., p. 19.

takes place more in individual program offices than what had previously occurred when FAA's Enforcement Division tracked all administrative and enforcement actions.[502] Importantly, the GAO found that the FAA "has not taken steps to evaluate if or determine how the program accomplishes" its goals.[503] "Key considerations for agency enforcement decisions state than an agency should establish an evaluation plan to determine if its enforcement policy achieves desired goals. Three of eight FAA offices have started to evaluate the effects of the Compliance Program, but two offices have not yet started," according to the GAO. "Three other offices do not plan to do so—in one case, because FAA has not told the office to," the GAO wrote.[504]

Without a central authority to oversee the Compliance Program's use across the agency, GAO concluded that FAA lacks controls to ensure that the program is working as intended.[505] To remedy this deficiency, GAO recommended that the FAA assign authority to an office to oversee the Compliance Program across program offices.[506] Such an office would then be able to collect and analyze data to monitor use of the Compliance Program and to assess the effectiveness of the program in meeting its goals.[507] The GAO concluded, "[W]ithout an evaluation, FAA will not know if the Compliance Program is improving safety or having other effects—intended or unintended."[508]

As a regulatory agency, the FAA must be able to effectively regulate Boeing and provide appropriate—and at times aggressive—oversight of Boeing. The public's safety depends on it, and the detailed investigative findings in this report makes that clear. Understanding the FAA's oversight structure, as well as the many problems it has recently encountered and the oversight challenges it still needs to confront, is important to understanding why the U.S. aviation regulatory system failed in such spectacular fashion with the certification of the 737 MAX aircraft and the FAA's actions after the crash of Lion Air flight 610.

[502] Ibid., pp. 25-26.
[503] Ibid, ("GAO Highlights" page).
[504] Ibid., ("GAO Highlights" page).
[505] Ibid., p. 34.
[506] Ibid.
[507] Ibid.
[508] Ibid., ("GAO Highlights" page).

5. Maneuvering Characteristics Augmentation System (MCAS)

-Maneuvering Characteristics Augmentation System (MCAS)-

INVESTIGATIVE FINDINGS

- Early in the MAX program, in 2013, Boeing intentionally sought to ensure MCAS was not defined as a new function in order to avoid increased costs and greater certification and pilot training impact.[509]

- Boeing engineers and an Authorized Representative (AR) raised concerns about MCAS relying on a single AOA sensor in 2015,[510] and the impact to MCAS from erroneous AOA data[511] and a pilot's ability to counteract repetitive MCAS activation in 2016.[512] These concerns were not investigated thoroughly enough and, in some cases, dismissed by other Boeing colleagues. Because there was no specific regulatory requirement to share these concerns with the FAA, Boeing and the AR chose not to inform the agency about these issues.

- Boeing sought to acquire internal approval to redesign MCAS and to obtain FAA approval to remove references to MCAS from pilot training material near simultaneously. On March 30, 2016, hours after the MCAS redesign was approved by the 737 MAX's senior program leadership,[513] Boeing sought, and the FAA separately approved, the removal of any references to MCAS from Boeing's Flight Crew Operations Manual (FCOM).[514]

- Boeing's Chief Project Engineer on the 737 MAX program was unfamiliar with key design aspects of MCAS when he approved of its design, including its reliance on a single AOA sensor and its ability to activate repeatedly.[515]

- Boeing's design of MCAS violated its own internal design requirements, which demanded that the system "not have any objectionable interaction with the piloting of the airplane" and "not interfere with dive recovery," which occurred in both 737 MAX crashes.[516]

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[509] See: Internal Boeing email, "PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, 9:10 PM, accessed at p. 93 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf and Boeing ITRACS Item, "MCAS/Speed Trim," 37MAXFCI-PDR AI22, BATES Number TBC T&I 549172-549173. (On file with the Committee).

[510] Boeing employee email, "MCAS Stab Rapid Reversal on PSIM Model," December 17, 2015, BATES Number TBC-T&I 010584 - TBC-T&I 010586 at TBC-T&I 010584, released at Hearing before the House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 121, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[511] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOC 2]," Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC T&I 246488 – T&I 246493 at T&I 246489. (On file with the Committee).

[512] Ibid. at TBC-T&I24690.

[513] Internal Boeing email, "Subject: 5-15 update," April 1, 2016, 3:28 p.m., BATES Number TBC T&I 255562. (On file with the Committee).

[514] Email from Mark Forkner to FAA, "Subject: MCAS lives in both FCCs," March 3, 2016 (On file with Committee).

[515] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes (BCA), May 11, 2020.

[516] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June 11, 2018, accessed at p. 170 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

INVESTIGATIVE FINDINGS - Continued

- In 2012, at the start of the 737 MAX program, it took a Boeing test pilot more than 10 seconds to respond to uncommanded[517] MCAS activation in a flight simulator, which the pilot found to be "catastrophic[.]"[518] Boeing never shared this information with the FAA, its MAX customers, or MAX pilots.

New Larger Engines Resulted in Aerodynamic Instability in Critical Situations

In 2011, facing a competitive threat from Airbus's new, more fuel efficient, single-aisle A320 aircraft, Boeing believed it did not have time to create a new plane from scratch.[519] Instead, it opted to modify its existing 737 NG aircraft to make it more fuel efficient.[520] To help accomplish this, Boeing installed, larger, more fuel efficient engines on this new 737 derivative airplane model dubbed the 737 MAX aircraft.[521]

The existing engines on the 737 NG aircraft were located under the wings and already hung relatively low to the ground, a vestige of the 737's original 1967 design—a time when stairs were more commonly used by passengers to board planes than jetways, and ground crews more commonly hand-lifted luggage into cargo holds, as opposed to using motorized belt loaders.[522] As a result, there was not enough ground clearance to simply swap out the old engines and replace them with new, larger, more efficient ones.[523]

The engines on the 737 NG have a ground clearance of 17 inches.[524] By comparison, Boeing's 757 model aircraft has a minimum clearance of 29 inches and Boeing's 787 Dreamliner has a minimum clearance of 28 inches.[525] The 737 NG engine hangs so low that the otherwise circular casing around it, known as a nacelle, is flattened at the bottom – giving it a look that some pilots have dubbed the "hamster pouch."[526]

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[517] MCAS was designed to activate automatically without any pilot command. Use of the term "uncommanded" in connection with MCAS activation here is for consistency with Boeing's own Functional Hazard Assessments which measured, "Uncommanded MCAS function operation to pilot reaction[,]" and observed that a "slow reaction time scenario (> 10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed." See Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, pp. 163-164 and 173-174, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[518] Boeing internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," November 1, 2012, BATES Number TBC T&I 131226-131227. (On file with the Committee).

[519] David Gelles, Natalie Kitroeff, Jack Nicas and Rebecca Ruiz, "Boeing Was 'Go, Go, Go' to Beat Airbus With the 737 Max," *New York Times*, March 23, 2019, accessed here: https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html

[520] Ibid.

[521] Ibid.

[522] Ralph Vartabedian, "How a 50-year-old design came back to haunt Boeing with its troubled 737 Max jet," *Los Angeles Times*, March 15, 2019, accessed here: https://www.latimes.com/local/california/la-fi-boeing-max-design-20190315-story.html

[523] Ibid.

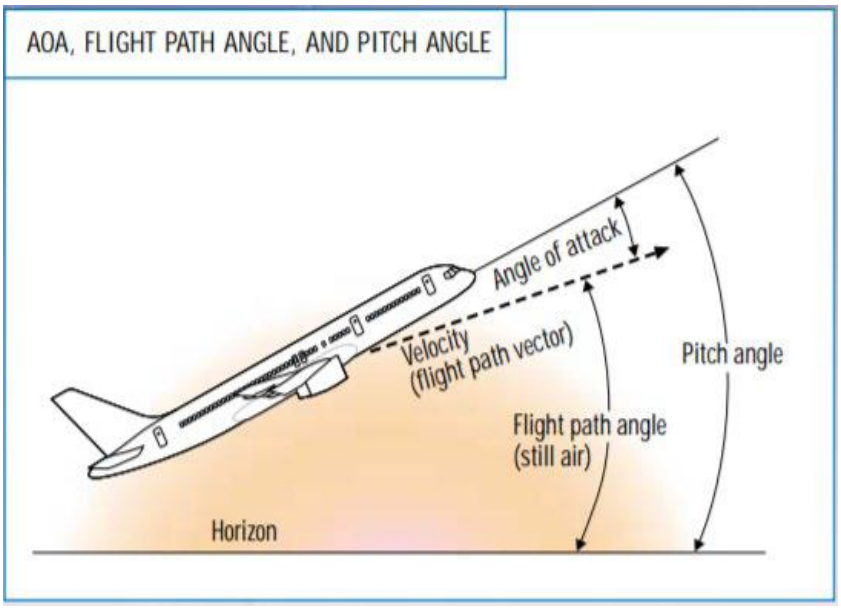
[524] Ibid.

[525] Ibid.

[526] Ibid.

What is Angle-of-Attack (AOA)?

Early in the development of the 737 MAX program, in order to help maintain enough ground clearance on the 737 MAX, Boeing mounted the new engines further forward on the wings and higher up on the aircraft.[527] This subsequently altered the plane's aerodynamics during certain flight maneuvers, especially during high angles of attack (AOA).[528] "Angle of attack is the angle between the oncoming air or relative wind and a reference line on the airplane or wing," according to a Boeing article from October 2000.[529] When the airplane was pitched up at a high AOA and pilots applied engine thrust, that thrust caused the airplane to pitch up even more, creating a risk that the airplane could enter a dangerous condition known as an aerodynamic stall, which is a loss of lift under the wings and causes the airplane to essentially fall out of the sky absent appropriate corrective action by the pilots, which in most cases would involve pushing the nose down so that air can flow across the wings and the airplane can regain lift.[530]

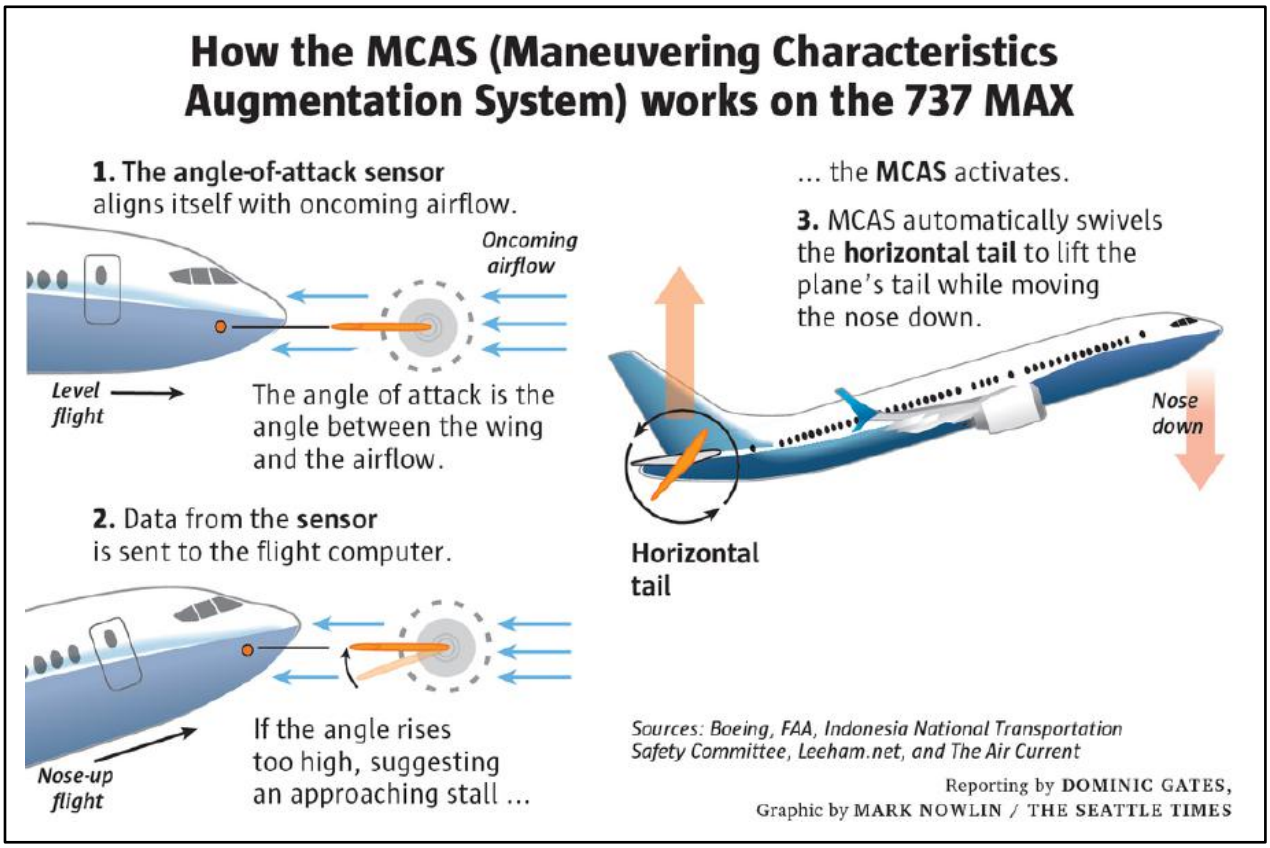


Source: "What is Angle of Attack?" *AERO Magazine*, The Boeing Company, October 2000.

In addition, when piloting the 737 MAX during a test maneuver known as a high speed wind-up turn, which is required for FAA certification and involves flying the plane at a high AOA, the force that pilots felt on the control column was not as smooth as required.[531] As pilots pulled back on the column during the maneuver, they could feel a slackening of resistance.[532] Conversely,

[527] Ibid.
[528] Ibid.
[529] "What is Angle of Attack?" *AERO Magazine*, The Boeing Company, October 2000, accessed here: https://www.boeing.com/commercial/aeromagazine/aero_12/attack_whatisaoa.html
[530] See: "Maneuvering Characteristics Augmentation System (MCAS)," SKYbrary, Flight Safety Foundation, accessed here: https://www.skybrary.aero/index.php/Maneuvering_Characteristics_Augmentation_System_(MCAS) and "Aerodynamic Stall Awareness and Avoidance," SKYbrary, Flight Safety Foundation, accessed here: https://www.skybrary.aero/index.php/Aerodynamic_Stall_Awareness_and_Avoidance and Andy Pazstor, Andrew Tangel, Alison Sider, "Between two deadly crashes Boeing moved haltingly to make 737 MAX fixes," *Wall Street Journal* April 1, 2019, accessed here: https://www.wsj.com/articles/between-two-deadly-crashes-boeing-moved-haltingly-to-make-737-max-fixes-11554164171?mod=hp_lead_pos1
[531] Dominic Gates & Mike Baker, "The inside story of MCAS: How Boeing's 737 MAX system gained power and lost safeguards," *Seattle Times*, June 22, 2019, accessed here: https://www.seattletimes.com/seattle-news/times-watchdog/the-inside-story-of-mcas-how-boeings-737-max-system-gained-power-and-lost-safeguards
[532] Ibid.

the FAA mandates that airplanes handle this maneuver with a smooth transition.[533] To address this, Boeing's engineers initially considered adding small metal vanes known as vortex generators on the wings.[534] This proposed fix did not prove to be satisfactory to address the issue, however. Ultimately, Boeing decided to add the Maneuvering Characteristics Augmentation System (MCAS) to the 737 MAX to help the aircraft compensate for those flight conditions.[535]


How the MCAS (Maneuvering Characteristics Augmentation System) works on the 737 MAX
1. The angle-of-attack sensor aligns itself with oncoming airflow.
Oncoming airflow
Level flight
The angle of attack is the angle between the wing and the airflow.
2. Data from the sensor is sent to the flight computer.
Nose-up flight
If the angle rises too high, suggesting an approaching stall ...
... the MCAS activates.
3. MCAS automatically swivels the horizontal tail to lift the plane's tail while moving the nose down.
Nose down
Horizontal tail
Sources: Boeing, FAA, Indonesia National Transportation Safety Committee, Leeham.net, and The Air Current
Reporting by DOMINIC GATES,
Graphic by MARK NOWLIN / THE SEATTLE TIMES

Source: Dominic Gates and Mike Baker, "The inside story of MCAS: How Boeing's 737 MAX system gained power and lost safeguards," *The Seattle Times*, June 22, 2019 (Updated: June 24, 2019).

As described in more detail above, MCAS is an automated system designed to activate if and when the 737 MAX reached, among other things, a high AOA. In such an event, MCAS would move the plane's horizontal stabilizer to push the plane's nose in a downward direction, to reduce

[533] 14 Code of Federal Regulations (CFR) § 25.203 "Stall characteristics," Federal Aviation Administration (FAA), Department of Transportation (DOT), January 1, 2011, accessed here: https://www.govinfo.gov/app/details/CFR-2011-title14-vol1/CFR-2011-title14-vol1-sec25-203

[534] See: Dominic Gates & Mike Baker, "The inside story of MCAS: How Boeing's 737 MAX system gained power and lost safeguards," *Seattle Times*, June 22, 2019, accessed here: https://www.seattletimes.com/seattle-news/times-watchdog/the-inside-story-of-mcas-how-boeings-737-max-system-gained-power-and-lost-safeguards and Jack Nicas, Natalie Kitroeff, David Gelles, and James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times*, June 1, 2019, accessed here: https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1

[535] Dominic Gates & Mike Baker, "The inside story of MCAS: How Boeing's 737 MAX system gained power and lost safeguards," *Seattle Times*, June 22, 2019, accessed here: https://www.seattletimes.com/seattle-news/times-watchdog/the-inside-story-of-mcas-how-boeings-737-max-system-gained-power-and-lost-safeguards

the angle of attack.[536] In both the Lion Air and Ethiopian Airlines crashes, erroneously high AOA data from faulty AOA sensors caused MCAS to keep pushing the plane's nose downward based on faulty data, which led to catastrophic consequences.[537] While every 737 MAX aircraft has two AOA sensors positioned on each side of the front of the aircraft, pre-crash versions of MCAS relied on AOA data from only a single AOA sensor at a time.[538] The MCAS software system, embedded in the airplane's flight control computer, would end up playing a central role in the MAX crashes.

Boeing Rejected the Idea of an MCAS Indicator Light

Boeing initially considered adding an MCAS light on the flight control panel that would have illuminated in the event that MCAS failed to activate The presence of an MCAS fail light on the flight control panel would have notified pilots of the presence of MCAS on the 737 MAX. Ultimately, however, Boeing rejected that idea. A mock-up of the MCAS indicator light was displayed in a November 8, 2012, "Preliminary Design Decision Memo," that was publicly released at the Committee's October 30, 2019, hearing on the 737 MAX.[539]

John Hamilton, then-Chief Engineer for the Boeing Commercial Airplanes (BCA) division of The Boeing Company, testified at that hearing and explained why Boeing decided to delete the MCAS indicator light saying, "[I]t was deleted … because the functionality was incorporated into the speed trim fail light."[540] In response to Questions for the Record (QFRs) from that hearing, then-Boeing Chief Executive Officer (CEO), Dennis Muilenburg, confirmed this line of thinking writing, "MCAS is an extension of the pre-existing Speed Trim function…."[541]

A May 2014 internal Boeing email also provides a summary of a "737 MAX Flight Controls/Pilots Meeting" that raised questions about how to annunciate an MCAS failure.[542] "With annunciation, failure is minor," the email said.[543] "Without annunciation, failure is major."[544] "Is it

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[536] "Maneuvering Characteristics Augmentation System (MCAS)," SKYbrary, Flight Safety Foundation, accessed here: https://www.skybrary.aero/index.php/Maneuvering_Characteristics_Augmentation_System_(MCAS)

[537] Final KNKT.18.10.35.04 Aircraft Accident Investigation Report, PT. Lion Mentari Airlines, Boeing 737-8 (MAX); PKLQP, Tanjung Karawang, West Java, Republic of Indonesia, 29 October 2018," Komite Nasional Keselamatan Transportasi (KNKT), Republic of Indonesia, issued October 25, 2019, (hereafter referred to as: Lion Air Flight 610 Final Aircraft Accident Investigation Report,") accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and Interim Investigation Report on Accident to the B737-8(MAX) Registered ET-AVJ operated by Ethiopian Airlines on 10 March 2019," Federal Democratic Republic of Ethiopia, Ministry of Transport, Aircraft Accident Investigation Bureau, released March 9, 2020, (hereafter referred to as: "Ethiopian Airlines Flight 302 Interim Investigation Report,") accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[538] Curt Devine and Drew Griffin, "Boeing relied on single sensor for 737 Max that had been flagged 216 times to FAA," *CNN*, April 30, 2019, accessed here: https://www.cnn.com/2019/04/30/politics/boeing-sensor-737-max-faa/index.html

[539] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, pp. 119-120, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[540] Ibid., p. 20.

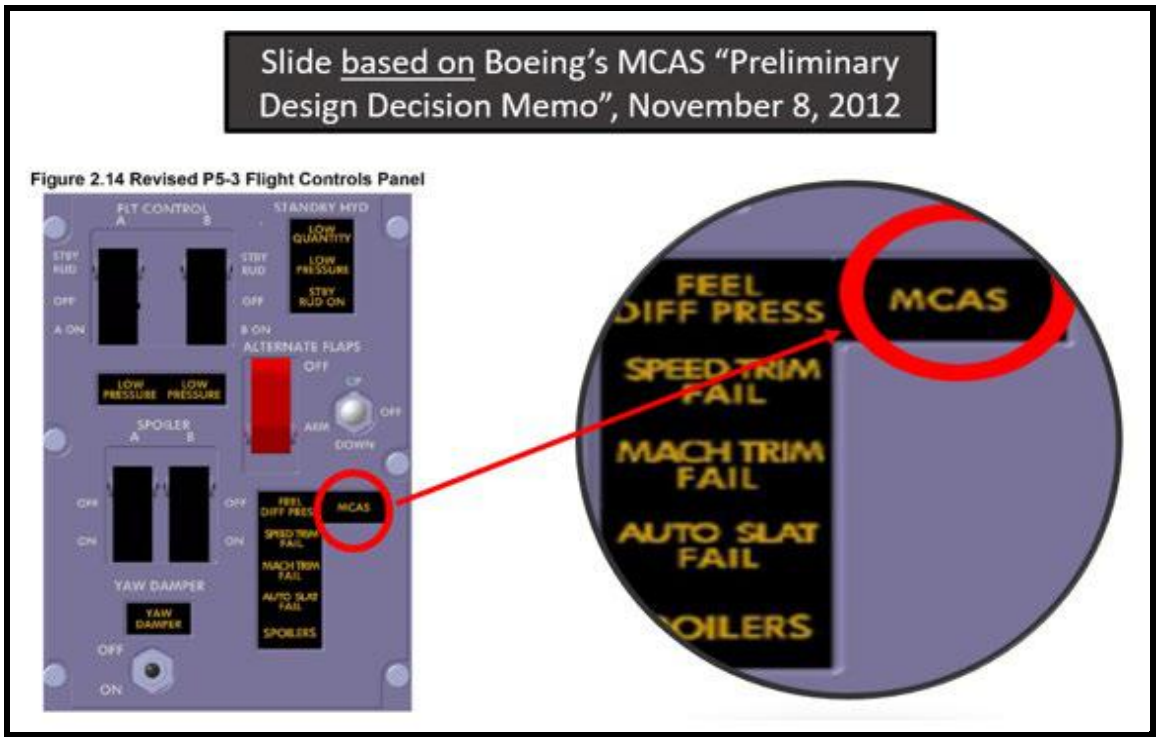
[541] Ibid., p. 277.

[542] Internal Boeing Email, "Subject: 737 MAX Flight Controls/Pilots Meeting," Sent: Tuesday, May 27, 2014, 11:53 AM, (Notes: "Meeting Date 5/27/2014 11:00 AM (recurring)," TBC-T&I 181331-181333 (On file with the Committee).

[543] Ibid.

[544] Ibid.

okay to not annunciate it, after all, what would the crew do? Should it be annunciated with the existing SPEED TRIM FAIL light," the email said. But it added, "The speed trim system is not all that reliable."[545]


Slide based on Boeing's MCAS "Preliminary Design Decision Memo", November 8, 2012
Figure 2.14 Revised P5-3 Flight Controls Panel
FEEL DIFF PRESS
MCAS
SPEED TRIM FAIL
MACH TRIM FAIL
AUTO SLAT FAIL
YAW DAMPER

The notion that MCAS was simply an extension of the speed trim system was a central tenet from Boeing during its certification. Technically, MCAS is part of the speed trim system.[546] However, many aviation experts have expressed concerns that this narrow definition was a strategy to muddy the waters around MCAS so that Boeing could claim that MCAS was not new or novel and therefore should not be subjected to greater scrutiny during certification. Greg Travis, a software expert and private pilot, published one of the first detailed articles on MCAS in the Institute of Electrical and Electronics Engineers' (IEEE's) magazine *SPECTRUM* in April 2019.[547] According to Travis, Boeing's efforts to describe MCAS as simply an extension of the MAX's "speed trim system" was an effort to "give shade and cover to the notion that MCAS in the 737 MAX was not new."[548]

[545] Ibid.
[546] "Preliminary Summary of the FAA's Review of the Boeing 737 MAX: Return to Service of the Boeing 737 MAX Aircraft, Version 1," Federal Aviation Administration, August 3, 2020, p. 23., accessed here: https://www.faa.gov/news/media/attachments/737-MAX-RTS-Preliminary-Sum11:53 amary-v-1.pdf
[547] Gregory Travis, "How the Boeing 737 Max Disaster Looks to a Software Developer," *IEEE Spectrum*, April 18, 2019, accessed here: https://spectrum.ieee.org/aerospace/aviation/how-the-boeing-737-max-disaster-looks-to-a-software-developer
[548] T&I Democratic staff email exchange with Gregory Travis, April 20, 2020.

A Plan to Downplay MCAS

Regardless of the technical merits of Boeing's argument that MCAS should be characterized as an extension of the speed trim system, Boeing also had other motivations to describe MCAS that way. In May 2013, a group of Boeing employees working on the 737 MAX met to address another concern: "If we emphasize MCAS is a new function there may be greater certification and training impact," one Boeing employee wrote in a June 7, 2013, email summarizing the minutes of that meeting.[549]

While Boeing did not hide MCAS from regulators, or even some airlines, it appears Boeing took efforts over the lifespan of the MAX program to downplay and deflect attention away from MCAS even after the Lion Air crash.[550]

Boeing has claimed it provided clear indications to both foreign and domestic regulators about MCAS. In a letter to the Committee on September 3, 2020, Boeing's Chief Counsel for Regulatory and Legislative Affairs wrote:

> These facts make it clear that Boeing did not hide MCAS from the FAA in connection with the 737 MAX's certification or its customers. Boeing employees repeatedly disclosed the existence of MCAS, over many years, during their communications with the FAA, foreign regulators, and customers. Their communications identified MCAS by name and stated expressly that it was a "new" system that was being added to the 737 MAX.[551]

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[549] Internal Boeing email, "PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, 9:10 PM, accessed at p. 93 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[550] See: Three months after the Lion Air crash Boeing was still arguing that its "rationale" to remove reference to MCAS from 737 MAX pilot training manuals "remains valid" and it still argued that differences "between the 737 NG and 737 MAX relating to the MCAS flight control law do not affect pilot knowledge, skills, abilities, or flight safety." See: Letter from Boeing ODA Deputy Lead Administrator to FAA Aircraft Evaluation Group, January 30, 2019, BATES Number TBC-T&I 297017 - TBC-T&I 297018, accessed at pp. 134-135 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; and Letter from FAA B-737 FSB Chair to Boeing, December 13, 2018, BATES Number TBC-T&I 297016, accessed here, at p. 133: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[551] Letter from Boeing Chief Counsel for Regulatory and Legislative Affairs to Committee on Transportation and Infrastructure, September 3, 2020. (On file with the Committee). As noted later in this section, in March of 2016, Boeing requested permission from the FAA to remove MCAS from the Flight Crew Operations Training Manual (FCOM), telling the FAA that MCAS, "only operates WAY outside of the normal operating envelope." See Internal Boeing email, "Subject: 5-15 update," April 1, 2016, 3:28 p.m., BATES Number TBC T&I 255562. (On file with the Committee). In January 2017 Boeing also asked the FAA to remove references to MCAS from the pilot differences tables for the 737 MAX. Email from Mark Forkner, former Chief Technical Pilot, The Boeing Company, to FAA employee, Subject: "a few DT updates please," Tuesday, January 17, 2017 19:00:58 (On file with the Committee). On November 6, 2018, Boeing issued an Operations Manual Bulletin (OMB) for that manual to provide pilots with critical information following the Lion Air crash, but that bulletin did not mention MCAS. See Lion Air Flight 610 Final Aircraft Accident Investigation Report, pp. 288-289. The next day FAA issued an Emergency Airworthiness Directive (AD) that, like Boeing's bulletin, did not mention MCAS. See FAA Emergency Airworthiness Directive (AD) 2018-23-51, November 7, 2018, accessed at: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf. Boeing finally issued a Multi Operator Message (MOM) to 737 fleet operators regarding MCAS

However, the issue at the Boeing employee meeting was not about whether Boeing should provide information about MCAS to the FAA. Rather, it was about **how** the information about MCAS should be communicated to the FAA. In this regard, multiple investigations have found that communication was problematic. For example, the Joint Authorities Technical Review (JATR) found:

- "[T]he content of certification deliverables would not have provided FAA technical staff with awareness of key details of the MCAS function on the B737 MAX, including architecture, signal inputs, and limits of authority."[552]

- "MCAS should have been considered a novelty (and therefore clearly highlighted to the FAA technical staff) owing to the important differences in function and implementation it has on the B737 MAX compared with the previous MCAS installed on the B767-C2 (tanker)."[553]

- "The FAA was not completely unaware of MCAS; however, because the information and discussions about MCAS were so fragmented and were delivered to disconnected groups within the process, it was difficult to recognize the impacts and implications of this system. If the FAA technical staff had been fully aware of the details of MCAS function, the JATR team believes the agency likely would have required an issue paper for using the stabilizer in a way that it had not previously been used. MCAS used the stabilizer to change the column force feel, not trim the aircraft . . . If an issue paper had been required, the JATR team believes it would have likely identified the potential for the stabilizer to overpower the elevator."[554]

According to the Department of Transportation Office of Inspector General (DOT OIG):

> Early in the process, Boeing included limited information in initial briefings to FAA on the MAX's flight control software, MCAS, which subsequently has been cited as a contributing or potentially contributing factor in both accidents. However, Boeing presented the software as a modification to the existing speed trim system that would only activate under certain limited conditions. As such, MCAS was not an area of emphasis in FAA's certification efforts and

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on November 10, 2018. According to Boeing, it did so, "responding to operator requests for additional information about the subject matter of the OMB and AD . . . [that] provided technical details and operational information regarding the MCAS function." See Boeing's response to Chair DeFazio's question for the hearing record, Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 276, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[552] See Joint Authorities Technical Review (JATR), October 11, 2019 (hereinafter referred to as "JATR Report"), p. 24, accessed here: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[553] JATR Report p. 23.

[554] JATR Report pp. 13-14.

therefore did not receive a more detailed review or discussion between FAA engineers and Boeing.[555]

In addition, a draft review of the MCAS certification process undertaken by the FAA following the Lion Air crash, "noted Boeing's document traceability and clarity of explanations were lacking in its revisions to MCAS and other system certification documents. FAA's post-accident review determined that an independent reviewer would not have been able to effectively review the safety assessment as a standalone compliance document or understand the full system functionality and linkage with other systems and functions."[556]

This makes it even more notable that Boeing employees were worried – in June of 2013 – that, "If we emphasize MCAS is a new function there may be greater certification and training impact[,]" and were crafting a plan to try to make sure that didn't happen.[557] Specifically, they planned to, "Treat [MCAS] as an addition to Speed Trim . . . Externally we would communicate it as an addition to Speed Trim. Internally continue using the acronym MCAS. …[558]

They agreed to run the strategy by an Authorized Representative (AR) in Boeing's Autoflight group "to ensure this strategy is acceptable."[559] An AR, as described previously, is a Boeing employee authorized to conduct certification work on behalf of the FAA, and is supposed to work to uphold the interests of the FAA and the flying public, not the company's private commercial interests. The Boeing employees also agreed to make sure that their technical familiarity presentation to the European Union Aviation Safety Agency (EASA) "is consistent with the intent that MCAS is an addition to Speed Trim."[560]

The Boeing AR concurred with Boeing's plan regarding its description of MCAS.[561] As stated in the summary of the meeting, "This will allow us to maintain the MCAS nomenclature while not driving additional work due to training impacts and maintenance manual expansions."[562]

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[555] DOT Office of Inspector General, "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Report No. AV2020037, June 29, 2020, p. 15, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[556] Ibid. at pp. 32-33.

[557] Internal Boeing email, "PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, 9:10 PM, accessed at p. 93 here:

[558] Internal Boeing email, "PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, 9:10 PM, accessed at p. 93 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[559] Ibid.

[560] Ibid.

[561] Boeing ITRACS Item, "MCAS/Speed Trim," 37MAXFCI-PDR AI22, BATES Number TBC T&I 549172-549173. (On file with the Committee).

[562] Internal Boeing email, "PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, 9:10 PM, accessed at p. 93 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

The intent of this plan was clear. It was not to avoid confusion about MCAS by regulators or 737 MAX pilots. The purpose of characterizing MCAS as an addition to speed trim was to avoid "greater certification and training impact."

Boeing's item tracking compliance system database, called ITRACS, that documented this decision suggested that "cost" was also a factor in the plan to downplay MCAS and to describe it as merely an addition to the Speed Trim System.[563] On May 21, 2013, as part of that strategy meeting, the issue was presented this way in Boeing's ITRACS database:

> Problem Statement: Every new buzzword represents a company and airline cost via changed manuals, changed training, changed maintenance manuals.
>
> Recommended Action: Investigate deletion of MCAS nomenclature and cover under the umbrella of 'revised speed trim'.[564]

In Boeing's recent letter to the Committee they have claimed that the records they have provided to the Committee regarding this May 2013 meeting shows that the team's manager accepted the "team analysis on keeping MCAS nomenclature." "The item was then closed," Boeing wrote. "In other words, after reviewing the issue, the team recommended, and their manager agreed, to continue to refer to MCAS by that name."[565]

What the letter did not indicate is that it seems both the Boeing AR and the team manager accepted **all** of the team's recommendations, which included referring to MCAS by name internally, and "Externally we would communicate it as an addition to Speed Trim." Since then, Boeing has, in fact, repeatedly characterized MCAS as an addition to speed trim. For example, in response to questions for the record from Chair DeFazio from the Committee's October 2019 hearing on the 737 MAX, Mr. Muilenburg, the then-CEO of Boeing, wrote: "MCAS is an extension of the pre-existing Speed Trim function…."[566]

In isolation, perhaps this "[t]reat as an addition to Speed Trim" strategy could be dismissed. The meeting, for instance, did not include senior Boeing officials. However, this was also not a simple ad hoc email exchange between a few Boeing colleagues. The meeting, which was officially documented in Boeing's compliance database, was focused on strategizing about how to describe MCAS to avoid greater certification and training impact for the 737 MAX.

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563 Boeing ITRACS Item, "MCAS/Speed Trim," 37MAXFCI-PDR AI22, BATES Number TBC T&I 549172-549173. (On file with the Committee).
564 Ibid.
565 Letter from Boeing Chief Counsel for Regulatory and Legislative Affairs to Committee on Transportation and Infrastructure, September 3, 2020. (On file with the Committee).
566 Mr. Muilenburg QFR responses, Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 277, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

May/June 2013
MCAS/Speed Trim - Strategy Meeting Data

[ITRACS Main Menu] [View Verbose] [View Threaded] [View Compressed] [View Summary] [View Alt Format] [Set Flag] [Action Request]

6-FEB-2020 14:33:39 37MAXFCI-PDR_AI22

Item Header:
Title: MCAS/Speed Trim
Primary Resp Person:
Secondary Resp Person:

Fix Need Date: 01-JUL-2013
ECD:
Phase: CLOSED Item is resolved, no further action required
Model: 737 MAX -8

Information Last Modified: 27-JUN-2013 10:46:49 US(Pacific)

Item Progress:

Date	Resp Person	Type	Attachments	Last Updt (USPac)
21-MAY-2013		ORIG	N	24-MAY-2013 08:38:21

Problem Statement: Every new buzzword represents a company and airline cost via changed manuals, changed training, changed maintenance manuals.

Recommended Action: Investigate deletion of MCAS nomenclature and cover under the umbrella of 'revised speed trim'.

07-JUN-2013		ANALYSIS	N	07-JUN-2013 08:29:23

6/7/13 Meeting Minutes:
1) GTTA left the name as MCAS but treated as analogous function as a speed trim type function.
2) If we emphasize MCAS is a new function there may be a greater certification and training impact.
3) Treat as an addition to Speed Trim.
4) Externally we would communicate it is an addition to Speed Trim.
5) Internally continue using the acronym MCAS (within variable names etc).
6) Work with AR on certification perspective to ensure this strategy is acceptable.
7) Make sure EASA Fam Tech presentation is consistent with intent that MCAS is an addition to Speed Trim.

07-JUN-2013		PROP_RES	N	21-JUN-2013 09:25:42

After speaking with the Autoflight AR, concurrence was provided that we can continue to use the MCAS nomenclature internally (variable names, etc) while still considering MCAS to be an addition to the Speed Trim function. This will allow us to maintain the MCAS nomenclatue while not driving additional work due to training impacts and maintenance manuals.

27-JUN-2013		PROP_RES	N	27-JUN-2013 10:37:24

Accepting team analysis on keeping MCAS nomenclature. Item can be closed.

27-JUN-2013		CLOSURE	N	27-JUN-2013 10:46:49

Action Item is complete and is closed.

Effect of MCAS on Pilot Differences Training

The Boeing employees that devised the MCAS strategy were not the only Boeing employees that appeared to worry about the consequences that MCAS could cause to the 737 MAX's certification and pilot training requirements There are five distinct levels of pilot "differences training" that the FAA may require for new or derivative aircraft. They are labelled "Level A" through "Level E" differences training requirements, and the requirements increase with each level of training.[567]

"Level A differences are those differences of which the flightcrew member needs to be aware, but which have little effect on systems operations," for instance.[568] The methods used for this level of training can include reading highlighted pages of operating manuals or training bulletins and no checking is required for whether or not the pilot has absorbed or retained this information.[569]

According to the FAA, "Level B differences are those differences in systems, controls, and indicators that have only minor procedural differences."[570] "Appropriate instructional methods for Level B differences include, but are not limited to, audiovisual presentations, lectures, and tutorial computer-based instruction (TCBI). A task or systems check for Level B differences must be conducted after training. Appropriate methods include an oral or written exam or TCBI self-test."[571]

Level E contains the highest training requirements, which require training in a full flight simulator or an aircraft in order "to attain or maintain [specific] knowledge, skills, or abilities."[572]

One of the principal goals of the 737 MAX program was that it would require no greater than Level B differences training for pilots to transition from flying the 737 NG to flying the 737 MAX aircraft. Even before an AR approved of the Boeing employee plan to describe MCAS as merely an addition to the speed trim system, efforts to avoid increased pilot training requirements were already well underway throughout the 737 MAX program.

On Saturday, May 4, 2013, several weeks before the MCAS strategy meeting referenced above, Michael Teal, the former Chief Project Engineer on the 737 MAX program, sent an email to senior chiefs and functional leaders on the MAX program and listed "14 open significant trade studies/risk issues." One of them specifically addressed the concern that MCAS could increase pilot training requirements:

> **Differences Pilot Training**: Ensuring that the level of change on the MAX keeps the Differences training to 16 hours or less of Level B training. Concerns include the impact of the resolution of 25.1322

[567] FAA Order 8900.1, Volume 3. General Technical Administration, Chapter 19. Flightcrew Member Training and Qualification Programs, Section 9. Safety Assurance System: Differences Training—All Training Categories, Flight Standards Information Management System (FSIMS), Federal Aviation Administration (FAA), accessed here, https://fsims.faa.gov/PICResults.aspx?mode=EBookContents&restricttocategory=all~menu
[568] Ibid.
[569] Ibid.
[570] Ibid.
[571] Ibid.
[572] Ibid.

trade[573] and the Autopilot roll saturation change driven by the addition of MCAS to the flight controls system.[574]

In a transcribed interview with Committee staff, Mr. Teal acknowledged that obtaining Level B training on the 737 MAX "was a design objective"[575] of the MAX program and that he had a role in ensuring that design objective was being met. "I think it's fair to say my job is to ensure that the airplane meets all of its requirements -- the regulatory requirements, the Boeing requirements, the customer requirements. And the differences training for an NG pilot to fly common with the MAX was a part of that, the requirements that we set out to meet as a team," he said.[576]

How MCAS was Presented to Regulators

Boeing engaged in multiple efforts to downplay the role and potential safety implications of MCAS on the MAX and attempted to abolish any reference to MCAS from various Boeing documents.[577] In March 2016, Boeing sought and received approval from the FAA to remove references to MCAS from the airplane's flight crew operations manual (FCOM) and training materials.[578] Boeing also failed to share critical information with the FAA or MAX customers regarding the fact that the company knew that it had taken one of Boeing's own test pilots more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator test, and the pilot found the condition to be "catastrophic[.]"[579]

Asked about why Boeing removed references to MCAS from pilot training documents at the Committee's October 2019 hearing , Dennis Muilenburg, then- CEO of Boeing, said: "[T]he intent was to provide the training materials that the pilots would need to fly the airplane, rather than try to educate them on the system details."[580] Muilenburg explained, "Again, our goal is to optimize what is in the training manual, so we don't add more information than what is useful for the pilots."[581]

That explanation, however, does not comport with the rationale provided in the June 2013 meeting minutes for **not** referencing MCAS externally. As the MCAS strategy made clear, it was

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[573] This is a reference to the Federal Aviation Administration's (FAA's) Advisory Circular number 25.1322-1 on "Flightcrew Alerting" that provides guidance for showing compliance with certain requirements of Title 14 of the Code of Federal Regulations (14 CFR), part 25, for the design approval of flightcrew-alerting functions. See Advisory Circular (AC), 25.1322-1 - Flightcrew Alerting, Federal Aviation Administration (FAA), December 13, 2010, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25.1322-1.pdf

[574] Boeing internal email from Former 737 MAX Chief Project Engineer to Boeing Commercial Airplanes (BCA) Senior Chiefs and Functional Leaders, "Subject: 737MAX Firm Configuration Status/Help Needed," Saturday, May 4, 2013, BATES Number TBC T&I 049683 - 49684. (On file with the Committee).

[575] Committee staff Transcribed Interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, Boeing Commercial Airplanes (BCA), May 11, 2020.

[576] Ibid.

[577] Email from Mark Forkner to FAA, "MCAS Lives in Both FCCs," Mar. 30, 2016.

[578] Ibid.

[579] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[580] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 98, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[581] Ibid at p. 97.

important to Boeing to limit any impact on increased certification and pilot training. Increases in either would have increased the cost of the 737 MAX program. Three key concerns: 1) that MCAS had the potential to increase certification scrutiny; 2) that MCAS could have led to greater pilot training requirements; and 3) that references to MCAS in training and other manuals could increase costs to both Boeing and its customer airlines, appear to have driven Boeing's efforts to downplay MCAS as much as possible.

To achieve those objectives, Boeing appears to have pushed the idea that MCAS was simply an extension of the Speed Trim System. While technically this is accurate, describing MCAS that way helped to obscure the fact that MCAS was a new function on commercial aircraft. To be clear, Boeing provided information to the FAA about MCAS, including some in which MCAS was characterized as new. However, the rationale for describing MCAS that way was clearly laid out in the meeting minutes referenced above that approved a strategy to help Boeing attempt to shield itself against greater certification and training impact. This strategy ran its course, promulgating the idea within Boeing that there was no need to overload pilots with information about MCAS. In the wake of the Lion Air and Ethiopian Airlines accidents, however, those arguments have been strongly condemned by the pilot community.[582] In addition, the Lion Air final accident investigation report pointed out the faulty logic in Boeing's rationale to omit information about MCAS from MAX pilots' training manuals.

> Without the awareness of the MCAS function, the flight crew would possibly recognize an MCAS activation as Speed Trim System (STS) input. MCAS behaves differently than the STS, it moves the horizontal stabilizer at a faster rate.[583]

Boeing has now reversed course on this issue. In October 2019, in testimony before the Committee, John Hamilton, then-Chief Project Engineer for Boeing Commercial Airplanes acknowledged this fact, stating, "I would say, since these accidents, we understand that pilots do want more information, and we are going to incorporate that in our flight crew training manual and flight crew operations manual."[584]

Whether Boeing's actions to remove references to MCAS from training manuals and its' lack of transparency regarding test data it had regarding the impact MCAS could have on a pilot's ability to maintain effective control of the 737 MAX airplane were intentionally deceptive, or represented unintentionally poor judgement, is difficult to know, but the result was the same. Boeing shielded references to MCAS and important information about MCAS from 737 MAX pilots.[585]

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[582] Benjamin Zhang, "Boeing's CEO explains why the company didn't tell 737 Max pilots about the software system that contributed to 2 fatal crashes," *Business Insider*, April 29, 2019, accessed here: https://www.businessinsider.com/boeings-ceo-on-why-737-max-pilots-not-told-of-mcas-2019-4

[583] Lion Air Flight 610 Final Aircraft Accident Investigation Report," p.196, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[584] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 34, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[585] Email from Mark Forkner to FAA, "MCAS Lives in Both FCCs," Mar. 30, 2016.

Maneuvering Characteristics Augmentation System (MCAS) – Timeline

November 1, 2012	November 8, 2102	May 4, 2103
A Boeing test pilot takes more than 10 seconds to respond to uncommanded MCAS activation in a flight simulator and finds the condition "catastrophic." Boeing repeatedly referred to that test data in internal documents but never relayed that information to the FAA or to MAX pilots because there was no specific requirement to share it.	A Boeing Preliminary Design Decision Memo shows plans for an MCAS annunciator on the flight deck of the 737 MAX to indicate if MCAS fails to activate. However, the annunciator was not ultimately included on the aircraft.	Michael Teal, former Chief Project Engineer on the 737 MAX program, sends an email to senior Boeing managers indicating "concerns" about the addition of MCAS to the flight controls system and its impact on Boeing's ability to obtain Level B (non-simulator) pilot differences training for 737 MAX pilots.
May-June 2013	**July 8, 2015**	**December 17, 2015**
Boeing employees devised a strategy on June 7, 2013, to treat MCAS as an "addition to Speed Trim" to help prevent increased "cost" due to changed manuals. The strategy, approved by a Boeing Authorized Representative (AR), is outlined in an email, saying: "If we emphasize MCAS is a new function there may be greater certification and training impact."	Boeing notes its test pilot's slow, "catastrophic" reaction time to uncommanded MCAS activation in its Coordination Sheet for the first time, saying, "A typical reaction time was observed to be approximately 4 seconds. A slow reaction time scenario (> 10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed." Boeing updated this record, citing this same information, six times from 2015 to 2018 but never shared this data with the FAA.	A Boeing AR asked in an email, "Are we vulnerable to single AOA sensor failures with the MCAS implementation or is there some checking that occurs?" In the end, MCAS was certified with a single AOA sensor and erroneous AOA data contributed to both 737 MAX accidents. Boeing is now implementing changes in the wake of both MAX crashes so that MCAS relies on two AOA sensors.
March 30, 2016 (8:00 am)	**March 30, 2016 (11:16 am)**	**June 15, 2016**
Keith Leverkuhn, Boeing's former 737 MAX program General Manager, and Michael Teal, former Chief Project Engineer on the MAX program, approve the redesign of MCAS that enables it to activate at lower speeds.	Mark Forkner, former 737 Chief Technical Pilot, emails an FAA official in the Seattle AEG at 11:16 a.m. requesting permission to remove references to MCAS from the MAX's Flight Crew Operations Manual and training material. Unaware of the MCAS redesign, the FAA official grants this request. The Committee has been unable to determine if Mr. Forkner was aware that Boeing had approved a design change to MCAS at the time he emailed FAA.	A Boeing AR Advisor emailed a colleague and asked, "What happens when we have faulty AOA or Mach number?" The colleague responds, "As for faulty AOA and/or Mach number…if they are faulty then MCAS shuts down immediately." Faulty AOA data was a major contributing factor in both MAX crashes and MCAS did not shut down in either of those accidents.
June 16, 2016	**October 29, 2018**	**March 10, 2019**
Referring to a Boeing test pilot's problem trimming the MAX due to repetitive MCAS activations, a Boeing engineer asks, "Is this considered a safety or cert[ification] issue?" On June 20, 2016, a colleague responds, "I don't think this is safety, other then [sic] the pilot could fight the MCAS input and over time find themselves in a large mistrim." This is exactly what happened on both MAX aircraft that crashed.	Lion Air flight 610 crashes 13 minutes after takeoff killing 189 people. MCAS is quickly determined to be a major factor in the crash. Faulty AOA data erroneously caused MCAS to repetitively activate more than 20 times as the pilots battled MCAS for control of the aircraft. These safety issues were identified by Boeing's engineers years before the Lion Air crash, but they were not appropriately addressed or dismissed.	Ethiopian Airlines flight 302 crashes six minutes after takeoff killing all 157 passengers and crew. The FAA is the last civil aviation authority to ground the 737 MAX on March 13, 2020, three days after the Ethiopian crash. The 737 MAX aircraft has been grounded worldwide ever since.

Fragmented Oversight of MCAS

Throughout the certification process, oversight of MCAS was fragmented and marred by confusion. Various references to MCAS were included in multiple FAA-related records, but FAA did not have a holistic understanding of MCAS or the potential implications of its operations on the aircraft or the flight crew.[586]

As noted previously, by November 2016, four months prior to FAA certification of the 737 MAX, the FAA had delegated 79 of 91 certification plans to Boeing, nearly 90 percent of its certification related tasks.[587]

The certification documents related to MCAS were contained in two primary certification plans (CP). These plans both dealt with the aircraft's flight controls systems. One was dubbed: "Flight Controls – Primary, Elevator and Stabilizer Control" or Stabilizer CP #13471.[588] The other was named: "Flight Controls – Autoflight (EDFCS/FCC) & Autothrottle," or EDFCS Certification Plan CP #13474.[589] The acronym EDFCS/FCC stands for Enhanced Digital Flight Control System/Flight Control Computer.

According to the National Transportation Safety Board (NTSB), the first of the certification plans, the Stabilizer CP, proposed that the FAA delegate all Flight Controls Primary & Secondary related compliance findings to Boeing.[590] "On April 14, 2015, the FAA approved the delegation of several deliverables; however, they indicated that the deliverable titled '737 Stabilizer System Description and Safety Analysis' (SSA)[,]" which was the deliverable related to MCAS, would be retained by the FAA and would not be proposed for delegation.[591] "In November 2016, Boeing submitted the 737 Stabilizer System Description and Safety Analysis (SSA), revision F, to the FAA for acceptance," the NTSB wrote.[592] "In December 2016, the FAA's response to Boeing was to 'accept' the submittal and with notation 'delegated SSA approval to ODA.'"[593]

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[586] "Boeing 737 MAX Flight Control System: Observations, Findings, and Recommendations," Joint Authorities Technical Review (JATR), October 11, 2019 (hereinafter referred to as "JATR Report"), pp 13-14, accessed here: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf

[587] DOT Office of Inspector General, "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Report No. AV2020037, June 29, 2020, p. 15, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[588] See: FAA Certification Plans for the 737 MAX-8, Federal Aviation Administration (FAA), BATES FAA-T&I 000194-000196 (On file with Committee), and "NTSB System Safety and Certification Specialist's Report," ID No. DCA19RA017, Office of Aviation Safety, National Transportation Safety Board (NTSB), August 21, 2019, see p. 260 in Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[589] Ibid.

[590] "NTSB System Safety and Certification Specialist's Report," ID No. DCA19RA017, Office of Aviation Safety, National Transportation Safety Board (NTSB), August 21, 2019, (included in Lion Air Flight 610 Final Aircraft Accident Investigation Report,) at p. 262, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[591] Ibid., pp. 262-263.

[592] Ibid.

[593] Ibid., p. 263.

The NTSB also noted that the second certification plan, the EDFCS CP, "indicated that approval of the EDFCS System Safety Analysis would be retained by the FAA and would not be proposed to be delegated to the Boeing ODA. The FAA retained approval of the SSA until revision K, submitted in January 2017. At that time, the FAA stamped the revision as 'rejected' due to the need to correct some information and simultaneously delegated approval of the SSA once the final edits were complete."[594] The EDFCS System Safety Analysis was one of three deliverables within the certification plan that the NTSB found were directly related to MCAS.[595] In March 2017, two months after this System Safety Analysis was delegated to Boeing, the 737 MAX achieved final FAA certification approval.[596]

Moreover, the Joint Authorities Technical Review (JATR) also found that MCAS should have been presented to the FAA as a novel system. If MCAS had been presented as a new and novel aviation technology, the 737 MAX would have been subjected to far greater FAA regulatory scrutiny and a more thorough technical assessment. The JATR noted that:

> The FAA was not completely unaware of MCAS; however, because the information and discussions about MCAS were so fragmented and were delivered to disconnected groups within the process, it was difficult to recognize the impacts and implications of this system. If the FAA technical staff had been fully aware of the details of MCAS function, the JATR team believes the agency likely would have required an issue paper for using the stabilizer in a way that it had not previously been used. MCAS used the stabilizer to change the column force feel, not trim the aircraft . . . If an issue paper had been required, the JATR team believes it would have likely identified the potential for the stabilizer to overpower the elevator.[597]

A total of 88 "issue papers" were written on the 737 MAX aircraft as part of the certification process—which described various features on the airplane.[598] This included eight issue papers addressing "systems avionics," four on "systems flight controls" and two addressing "systems software."[599] But none were written specifically to address MCAS.

Military MCAS vs. Commercial 737 MAX MCAS

The first time Boeing added MCAS to a commercial aircraft was on the 737 MAX. However, Boeing had previously added MCAS to the U.S. Air Force's KC-46A Pegasus refueling tanker, which was a derivative of Boeing's commercial 767 airplane.[600] But there are significant differences between

[594] Ibid, p.265.
[595] Ibid, pp.265-266.
[596] "Boeing 737 MAX 8 Earns FAA Certification," Press Release, The Boeing Company, March 9, 2017, accessed here: https://boeing.mediaroom.com/2017-03-09-Boeing-737-MAX-8-Earns-FAA-Certification
[597] JATR Report, pp 13-14.
[598] 737 MAX Issue Papers, Federal Aviation Administration (FAA), BATES Number FAA-T&I 000197-000199. (On file with Committee).
[599] Ibid.
[600] See: John A. Tirpak and Brian W. Everstine, "USAF Reviewing Training After MAX 8 Crashes; KC-46 Uses Similar MCAS," *Air Force Magazine*, March 22, 2019, accessed here: https://www.airforcemag.com/usaf-reviewing-training-after-max-8-crashes-kc-46-uses-similar-mcas-system; Alison Sider and Andrew Tangel, "Before 737 MAX, Boeing's Flight-Control System Included Key Safeguards," *Wall Street Journal*, September 29, 2019, accessed here:

the operational design of MCAS on the KC-46 tanker and on the 737 MAX. On the KC-46 tanker, MCAS was given authority to move the plane's horizontal stabilizer only once per activation, not repeatedly as it was able to do on the 737 MAX. It was also given only limited power to push the plane's nose downward on the KC-46 tanker, which made it easier for pilots to counteract MCAS if necessary.[601] Importantly, the KC-46 tanker has at least two AOA sensors feeding data into MCAS, as opposed to a single AOA sensor like on the pre-crash design of the 737 MAX's version of MCAS. Finally, on the KC-46 tanker pilots could deactivate MCAS by simply pulling back on the stick, as opposed to having to perform a runaway stabilizer trim procedure.[602]

Initially, MCAS on the MAX was designed to activate only at higher speeds and in conditions not normally experienced in commercial flight. MCAS was only authorized to activate above a certain G-force and above a certain AOA.[603] As originally designed, MCAS was only capable of moving the horizontal stabilizer a maximum of 0.6 degrees.[604]

However, in March 2016, one year prior to the FAA's certification of the 737 MAX, when Boeing test pilots found the MAX was not handling well when nearing stalls at lower speeds, Boeing redesigned MCAS to enable it to activate at lower speeds.[605] Moreover, the new version of MCAS was capable of moving the horizontal stabilizer a maximum of 2.5 degrees (as opposed to 0.6 degrees as originally designed).[606] This was a significant technical change with dramatic operational implications. Repeated bursts of the MAX's horizontal stabilizer due to the activation of MCAS placed both Lion Air flight 610 and Ethiopian Airlines flight 302 into unrecoverable dives, which violated Boeing's own internal MCAS design requirements.[607]

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https://www.wsj.com/articles/before-737-max-boeings-flight-control-system-included-key-safeguards-11569754800; and "KC-46/737 MAX MCAS," Media Factsheet, U.S. Air Force, March 21, 2019. (On file with the Committee).

[601] Ibid.

[602] Ibid.

[603] Jack Nicas, Natalie Kitroeff, David Gelles, and James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times,* June 1, 2019, accessed here; https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1

[604] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 - TBC T&I 191232 at TBC T&I 191229 (On file with Committee); See also Jack Nicas, Natalie Kitroeff, David Gelles, and James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times*, June 1, 2019, accessed here; https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1

[605] Jack Nicas, Natalie Kitroeff, David Gelles, and James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times*, June 1, 2019, accessed here; https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1

[606] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 161 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Jack Nicas, Natalie Kitroeff, David Gelles, and James Glanz, "Boeing Built Deadly Assumptions Into 737 Max, Blind to a Late Design Change," *New York Times*, June 1, 2019, accessed here: https://www.nytimes.com/2019/06/01/business/boeing-737-max-crash.html?searchResultPosition=1

[607] See: Lion Air Flight 610 Final Aircraft Accident Investigation Report, p. 196, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf; Ethiopian Airlines Flight 302 Interim Investigation Report, p. 131, accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at pp. 161-162 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-

Redesigning MCAS

On Wednesday, March 30, 2016, Boeing held a "737MAX Leadership Review" meeting in a 4th floor conference room on its Everett, Washington, campus. Senior leaders on the MAX program were given a presentation by Boeing's engineers regarding the proposed redesign of MCAS.[608] The presentation was titled: "737 MAX / Stall Characteristics – Mitigation" and it included a "Stall Characteristics Go-Forward Plan."[609]

The approval of the redesign of the MCAS software was noted in an internal Boeing email on April 1, 2016, from a manager in the Aerodynamics Stability & Control group.[610] Under a heading titled "737MAX: Basic stall characteristics," the manager wrote that in a meeting with Keith Leverkuhn "on 3/30, the FC [Flight Control] configuration was approved as the mitigation for basic stall characteristics."[611] "Additionally, an update to the MCAS control law was approved to address a special case of high altitude, flaps up stall characteristics."[612]

Boeing's presentation regarding MCAS's redesign suggested that they had an "FAA Communication Plan,"[613] which indicated Boeing and FAA pilots would test the redesigned MCAS software in the E-Cab simulator[614] around June 13, 2016, and that Boeing and FAA pilots would fly the redesigned MCAS software around July 11, 2016, to test "maneuver procedures and stall characteristics[.]"[615]

In response to questions from Chair DeFazio and Subcommittee on Aviation Chair Larsen, Boeing stated, "On numerous occasions, Boeing shared with the FAA and international regulators that MCAS's final design had changed from its earlier parameters, and that its operating range had expanded to include low-speed conditions."[616] Boeing also noted that, "FAA personnel also observed the operation of the expanded MCAS during certification flight testing."[617]

While the new operating range of MCAS was included in certain communications with FAA, MCAS, in general, was not an area of particular emphasis.

0159, Model: 737-MAX (-7/8/9), Revision G, June, 11/2018, accessed at p. 170 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

608 "737 MAX / Stall Characteristics – Mitigation," Aero S&C, March 30, 2016, BATES Number TBC-T&I 214928-214941 (On file with Committee).

609 Ibid.

610 Internal Boeing email, "Subject: 5-15 update," April 1, 2016, 3:28 p.m., BATES Number TBC T&I 255562. (On file with Committee).

611 Ibid.

612 Ibid.

613 "737 MAX / Stall Characteristics – Mitigation," Aero S&C, March 30, 2016, BATES Number TBC-T&I 214928-214941 at p.3, TBC-T&I 214930 and p. 6, TBC-T&I 214933 (On file with Committee).

614 An E-Cab is an "Engineering" flight simulator. See: "The "e-cab" – A Test Flight Deck," The Boeing Company, accessed here: http://www.boeing.com/commercial/737max/news/the-e-cab-a-test-flight-deck.page

615 "737 MAX / Stall Characteristics – Mitigation," Aero S&C, March 30, 2016, BATES Number TBC-T&I 214928-214941 at p. 6, TBC-T&I 214933 (On file with Committee).

616 "Response to Question 7 and Related Questions," (Informally referred to as the "Boeing MCAS Narrative"), The Boeing Company, response to the Committee on Transportation and Infrastructure, BATES Number TBC T&I 372821-372832 at TBC T&I 372825 (On file with the Committee).

617 Ibid.

According to the Department of Transportation's Office of Inspector General:

> Early in the process, Boeing included limited information in initial briefings to FAA on the MAX's flight control software, MCAS, which subsequently has been cited as a contributing or potentially contributing factor in both accidents. However, Boeing presented the software as a modification to the existing speed trim system that would only activate under certain limited conditions. As such, MCAS was not an area of emphasis in FAA's certification efforts and therefore did not receive a more detailed review or discussion between FAA engineers and Boeing.[618]

When responding to a question from committee staff about whose job it would be at Boeing to inform the FAA about a change to MCAS, Mr. Teal noted, "…the certification plans would have to be updated . . ."[619] However, "[T]he JATR team found that the certification plans and some certification deliverables (e.g., the preliminary system safety assessment (PSSA)) were not updated to describe the expansion of the MCAS function for the low Mach portion of the flight envelope and for compliance with stall-related requirements."[620]

Through its investigation, the Committee also learned that the FAA—in its own review of MCAS in the wake of the Lion Air crash—determined that although there were gaps in the information that Boeing provided to FAA about MCAS they did not identify **any** "noncompliances."[621] The FAA's determination was listed in a draft report that they never finalized, but that was reviewed by the Committee. That report and its conclusion, that there were no "noncompliances" despite the fact Boeing did not share all critical and current certification records with the FAA, highlights significant regulatory and oversight gaps at the FAA and the lack of an effective regulatory aviation certification process. *(See Post-Accident Response section for more details on this report and its findings).*

Communication Issues

Overall, the Committee's investigation found extraordinarily poor communication between Boeing and the FAA, in addition to fragmented and ad hoc communication within FAA offices that played critical roles in the certification process. Other investigative bodies have reached similar conclusions.[622] These communications failures prevented a full view of vitally important technical issues that were central to the certification process.

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[618] DOT Office of Inspector General, "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Report No. AV2020037, June 29, 2020, p. 15, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[619] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, Boeing Commercial Airplanes (BCA), May 11, 2020.

[620] JATR Report.

[621] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020).

[622] JATR report, pp. 13-14, and DOT Office of Inspector General, "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Report No.

According to the JATR report, for instance, "The [FAA's Aircraft Evaluation Group] AEG should have deeper involvement during the certification process and collaborate closely with FAA's Aircraft Certification Service (AIR) to ensure they have the proper knowledge to make informed decisions about operational suitability issues that may be affected by certification details . . . Pilots working in the certification process may not have complete knowledge of operational issues, while pilots working in the operational evaluation process may not have complete knowledge of certification issues. This may contribute to a lack of communication between the two processes."[623]

In addition, the DOT Special Committee noted that the "complexity" of merging older and newer technologies on the 737 MAX meant that "in some cases, communications were fragmented. No holistic assessment of total system operational safety risk was required, or presented, that might have provided a broader review of safety risk to various management levels in the Boeing and FAA organizations. This holistic assessment would also serve to enhance communication of assumptions and feedback of data across the global aviation system," the report concluded.[624]

If the FAA had had a more comprehensive understanding of MCAS at the time the 737 MAX was undergoing certification, it is likely that it would have been classified as a "safety critical system" and would have resulted in much greater FAA scrutiny. At a Committee hearing in May 2019, Chair DeFazio raised this question with then-Acting FAA Administrator Dan Elwell:

> Mr. DEFAZIO. OK. Then is the MCAS a safety critical system, in your opinion?
>
> Mr. ELWELL. I didn't make that designation, but it seems to me that, yes, it is.[625]

The issues highlighted above had a serious impact on FAA's ability to have a clear and complete picture of the potential technical and operational impacts of MCAS on the 737 MAX aircraft. While Boeing couched MCAS as simply an extension to the previously existing Speed Trim System, MCAS had never been previously incorporated onto a commercial airplane. It was also fundamentally different than Boeing's design of the MCAS system incorporated onto the U.S. Air Force's KC-46 tanker and it should have been designated a safety critical system, which would have mandated a more thorough review.

AV2020037, June 29, 2020, p. 15, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[623] JATR report, pp. 44-45.

[624] Official Report of the Special Committee to Review the Federal Aviation Administration's Aircraft Certification Process, DOT Special Committee Report, pp. 36-37, accessed here: https://cms8.dot.gov/sites/dot.gov/files/2020-01/scc-final-report.pdf

[625] Hearing titled, "Status of the Boeing 737 MAX," House Committee on Transportation and Infrastructure, Subcommittee on Aviation, 116th Congress, First Session, May 15, 2019, pp. 28-29 accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

MCAS was Vulnerable to Single AOA Sensor Failure

In order to determine when to activate, MCAS relies on data from AOA sensors on the aircraft. Each 737 MAX is equipped with two AOA sensors, one on each side of the aircraft.[626] However, MCAS was designed to rely on data from only one AOA sensor at a time to determine whether to push the plane's nose downward.[627] MCAS alternated which individual AOA sensor it relied upon on each flight, from the left AOA sensor to the right AOA sensor and vice versa.[628] Because MCAS relied upon only one AOA sensor input at a time, this meant that, if the AOA sensor upon which MCAS was depending malfunctioned, and erroneously indicated a high AOA, MCAS would activate repeatedly and keep pushing the nose of the plane down unless the pilot knew how to effectively deactivate MCAS.

The fact that the 737 MAX's MCAS relied upon a single AOA sensor was problematic and has been widely criticized.[629] As the American Society for Engineering Education reported: "That MCAS apparently was vulnerable to a single point of failure 'should never have been permitted,' says Guy Gratton, an aeronautical engineer and visiting professor at Cranfield University in the United Kingdom. 'Redundancy is a core idea, especially in a complicated system where lives are at stake,' adds Karl Smith, cooperative learning professor of engineering education at Purdue University."[630] The MCAS system on the U.S. Air Force's KC-46 tanker, for instance, relies on two AOA sensors.[631]

The Lion Air final accident report also observed: "[T]he design of MCAS relying on input from a single AOA sensor, made [the 737 MAX's] Flight Control System susceptible to a single failure of AOA malfunction. During the accident flight, the scenario was initiated by a single failure, a high bias in AOA sensor. This high bias resulted in several aircraft level effects including stick shaker, erroneous airspeed and altitude displays and MCAS after the flaps were retracted."[632]

Boeing's Functional Hazard Assessment regarding pilot reaction to uncommanded MCAS function did not rate the system as being hazardous enough to require redundant features, such as multiple AOA sensors.[633] However, in its "analysis of hazardous and catastrophic failure conditions" generally, the FAA has written:

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626 Dominic Gates, "FAA cautions airlines on maintenance of sensors that were key to 737 MAX crashes," *Seattle Times*, August 20, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-cautions-airlines-on-maintenance-of-sensors-that-were-key-to-737-max-crashes

627 Ibid.

628 Ibid.

629 Curt Devine and Drew Griffin, "Boeing relied on single sensor for 737 Max that had been flagged 216 times to FAA," *CNN*, April 30, 2019, accessed here: https://www.cnn.com/2019/04/30/politics/boeing-sensor-737-max-faa/index.html

630 Mark Matthews and Charles Q. Choi, "Compass Course," *PRISM*, American Society for Engineering Education (ASEE), December 2019, accessed here: http://www.asee-prism.org/compass-course

631 "KC-46/737 MAX MCAS," Media Factsheet, U.S. Air Force, March 21, 2019. (On file with Committee).

632 "NTSB System Safety and Certification Specialist's Report," ID No. DCA19RA017, Office of Aviation Safety, National Transportation and Safety Board (NTSB), August 21, 2019, p. 194, (included in Lion Air Flight 610 Final Aircraft Accident Investigation Report,) accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

633 Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 163 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

> No catastrophic failure condition . . . should result from the failure of a single component, part, or element of a system. Experienced engineering judgment and service history should show that a catastrophic failure condition by a single failure mode is not a practical possibility. The logic and rationale used in the assessment should be so straightforward and obvious that the failure mode simply would not occur unless it is associated with an unrelated failure condition that would, in itself, be catastrophic.[634]

The frailty of AOA sensors was well known to the FAA prior to the certification of the 737 MAX.[635] They are mounted on the plane's fuselage near the nose and have a long history of known risks of damage and failure. According to a 2019 analysis by *Bloomberg*, "There are at least 140 instances since the early 1990s of [AOA] sensors on U.S. planes being damaged by jetways and other equipment on the ground, or striking birds in flight. In at least 25 cases in the U.S., Canada and Europe, the damage triggered cockpit alerts or emergencies."[636] In a slightly different analysis, *CNN* identified "at least 216 reports of AOA sensors failing or having to be repaired, replaced or adjusted since 2004," according to data from the FAA's Service Difficulty Reporting website.[637]

Boeing Internal Email
December 17, 2015

"ARE WE VULNERABLE TO SINGLE AOA SENSOR FAILURES WITH THE MCAS IMPLEMENTATION OR IS THERE SOME CHECKING THAT OCCURS?"

Fifteen months prior to the FAA's certification of the MAX, in March 2017, a Boeing engineer raised a question about leaving MCAS dependent upon just one AOA sensor. In a December 17, 2015, internal Boeing email, the Boeing engineer who was also an AR, asked, "Are we vulnerable to single AOA sensor failures with the MCAS implementation or is there some checking that occurs?"[638] The AR's concern proved remarkably prophetic as it was erroneous AOA data on both Lion Air flight 610 and Ethiopian Airlines flight 302 that caused MCAS to activate leading to those crashes.[639]

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634 "System Safety Analysis and Assessment for Part 23 Airplanes," Advisory Circular, AC No: 23 .1309-1E, Federal Aviation Administration (FAA), November 17, 2011, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC%2023.1309-1E.pdf

635 "Airworthiness Directive, Airbus Airplanes, Federal Aviation Administration (FAA), Notice of Proposed Rulemaking (NPRM), 14 CFR Part 39, [Docket No. FAA–2015–4810; Directorate Identifier 2015–NM–090–AD], *Federal Register* / Vol. 80, No. 218 / Thursday, November 12, 2015 / Proposed Rules, accessed here: https://www.govinfo.gov/content/pkg/FR-2015-11-12/pdf/2015-28559.pdf

636 Alan Levin and Ryan Beene, "Sensors Linked to Boeing 737 Crashes Vulnerable to Failure," *Bloomberg*, April 10, 2019, accessed here: https://www.bloomberg.com/news/articles/2019-04-11/sensors-linked-to-737-crashes-vulnerable-to-failure-data-show

637 Curt Devine and Drew Griffin, "Boeing relied on single sensor for 737 Max that had been flagged 216 times to FAA," *CNN Investigates*, April 30, 2019, accessed here: https://www.cnn.com/2019/04/30/politics/boeing-sensor-737-max-faa/index.html

638 Boeing employee email, "MCAS Stab Rapid Reversal on PSIM Model," December 17, 2015, BATES Number TBC-T&I 010584 - TBC-T&I 010586 at TBC-T&I 010584, released at Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 121, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

639 Lion Air Flight 610 Final Aircraft Accident Investigation Report, p. 195, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

Squawk and Repetitive MCAS Activation

On June 13, 2016, a few months after Boeing redesigned MCAS to give it more authority a Boeing test pilot observed that MCAS countered his attempts to trim the plane while flying a low-speed maneuver.[640] This situation raised concern with the same engineer who had previously asked about the single AOA sensor vulnerability.[641] In reviewing a plot of the test flight data, this engineer noted that the "ratchiness" of MCAS was causing the airplane to oscillate and recommended that the issue be further examined via Boeing's "squawk" process.[642]

A squawk is the term used to describe a problem with an airplane.[643] Following the June 13, 2016, flight, one of the test pilots entered the problem into Boeing's reporting system where squawks are tracked until they are resolved.[644]

This concern regarding the ability of pilots to effectively counteract repetitive MCAS activations was incredibly prescient as both the Lion Air and Ethiopian Airlines flights experienced uncontrolled oscillations from MCAS activations that led to catastrophic loss of command of the MAX aircrafts.[645] Unfortunately, like the engineer's previous question about MCAS relying on a single AOA sensor, the new concerns were ultimately dismissed.[646]

In a written response to the Committee about MCAS, Boeing said:

> The technical discussions of MCAS also included the possibility of a faulty angle of attack sensor potentially leading to repeated MCAS activation. After evaluating the issue, the group of technical experts and pilots involved in this discussion determined, based on their collective expertise, that there was no need to redesign MCAS to address this possibility because the flight crew would be able to manage the condition using … well-understood piloting techniques and procedures ….[647]

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[640] Boeing internal email, "Subject: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOCK 2]," Monday, June 13, 2016, 6:17 PM, BATES Number TBC-T&I246488 – TBC-T&I246493 at TBC-T&I246492. (On file with Committee).
[641] Ibid at TBC-T&I246490, TBC-T&I246491, and TBC-T&I246492.
[642] Ibid at TBC-T&I246490.
[643] Rod Machado, "Using the Airplane Squawk Sheet and Squawk Etiquette," *Disciplines of Flight,* May 25, 2017, accessed here: https://disciplesofflight.com/airplane-squawk-sheet/ [644] Boeing internal email, Subject: "Squawk for MCAS trim Event," Thursday, June 16, 2016 1:07 PM; TBC-T&I220826 – TBC-T&I220827 at TBC-T&I220826 (On file with the Committee).
[644] Boeing internal email, Subject: "Squawk for MCAS trim Event," Thursday, June 16, 2016 1:07 PM; TBC-T&I220826 – TBC-T&I220827 at TBC-T&I220826 (On file with the Committee).
[645] See: Lion Air Flight 610 Final Aircraft Accident Investigation Report, p. 78, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and Ethiopian Airlines Flight 302 Interim Investigation Report, pp. 10-11, accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf
[646] Boeing internal email, Subject "RE: Discussion of MCAS Characteristics," Wednesday, June 22, 2016 1:59 PM; TBC-T&I292457 – TBC-T&I292458 at TBC-T&I292457.
[647] "Response to Question 7 and Related Questions," (Informally referred to as the "Boeing MCAS Narrative"), The Boeing Company, response to the Committee on Transportation and Infrastructure, BATES Number TBC T&I 372821-372832 at TBC T&I 372829 (On file with the Committee).

On June 15, 2016, a Boeing engineer emailed several colleagues in reference to this issue and asked: "What happens when we have faulty AOA or Mach number?"[648] Another Boeing engineer responded, "As for faulty AOA and/or Mach number … if they are faulty then MCAS shuts down immediately."[649] That may have been the planned intent, but that did not happen on either the Lion Air or Ethiopian Airlines flights. In both cases faulty AOA data played critical roles in the crashes, and MCAS did not shut down due to erroneous AOA data received by MCAS.

Boeing Internal Email
June 16, 2016

"I DON'T THINK IT IS SAFETY, OTHER THAN THE PILOT COULD FIGHT MCAS INPUT AND OVER TIME FIND THEMSELVES IN A LARGE MISTRIM."

Further, another engineer who raised questions in a June 16, 2016, email to colleagues about these new concerns with MCAS was advised that the issue was not safety-related.[650] On June 20, 2016, the engineer who responded to this second engineer, said that the concern was about meeting technical certification requirements and wrote, "I don't think it is safety, other than the pilot could fight the MCAS input and over time find themselves in a large mistrim."[651]

Two days later, on June 22, 2016, an "MCAS Review" meeting was held to resolve the issue. Meeting participants largely supported the prevailing narrative in the email exchanges that preceded the meeting suggesting the observed issue with MCAS's "ratchiness" (or repetitive activation) was not a significant concern.[652] Rather, as indicated in the notes from the meeting that are depicted below, the effort needed to address the MCAS issue was described as an "easy fix" and that the problem itself posed "no real requirement violation."[653]

Boeing Internal Email
June 15, 2016

"WHAT HAPPENS WHEN WE HAVE FAULTY AOA OR MACH NUMBER?"

Further, in reference to the concern about "fail high AOA or fail high Mach resulting in MCAS motion"—in other words, that a false reading of a high AOA or a false reading of high airspeed—meeting participants determined that other systems would be reacting to the failure and that there was "[n]o need to redesign to address this issue."[654]

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[648] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOC 2]," Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC T&I 246488 – T&I 246493 at T&I 246489. (On file with Committee).
[649] Ibid.
[650] Boeing internal email, "Subject: RE: Squawk for MCAS trim Event," June 20, 2016, BATES Number TBC T&I 220826 - TBC T&I 220827 at TBC T&I 220826. (On file with the Committee).
[651] Ibid.
[652] Boeing internal email, "Subject: RE: Discussion of MCAS Characteristics," Wednesday, June 22, 2016 1:59 PM, BATES Number TBC T&I 292457. (On file with the Committee).
[653] Ibid.
[654] Ibid.

The meeting minutes of the June 22, 2016, MCAS Review state:

> **1. Trim Capability – Squawked**
> MCAS was not allowing pilot to trim at 1.13Vsr (would take out whatever trim was input). Resolution: move AOA trip higher to avoid low Mach 1.13Vs trims, easy fix / small work statement. No real requirement violation, however it will reduce the work load when demonstrating cert conditions.
> Some discussion on fail high AOA or fail high Mach resulting in MCAS motion. Conclusion: other systems will be reacting to the failure such as March trim or stick shaker, MCAS is small in comparison. No need to redesign to address this.[655]

The bottom of the email describing the meeting minutes stated: "All changes are minimal / low collateral damage, therefore no additional flight testing."[656] The reference to "1.13Vs trims" in the email was a reference to the stalling speed. The stalling speed (Vs) is the minimum steady flight speed at which the airplane is controllable.[657] The nomenclature "Vsr" is the reference to stall speed.[658]

Faulty Assumptions, Fatal Timing

Aside from the concerns raised by Boeing engineers about the impact of faulty AOA data on MCAS and the ability of MAX pilots to be able to counteract repetitive MCAS activation, Boeing also had evidence from its own test results showing that a test pilot took more than 10 seconds to respond to uncommanded MCAS activation, a condition the pilot found to be "catastrophic[.]" In the event that MCAS activated unexpectedly Boeing assumed that such a situation would look and feel to pilots like a condition known as runaway stabilizer trim—a condition that involves the electric trim motor suddenly moving the horizontal stabilizer toward the full nose-up or nose-down stop. Stabilizer trim runaway is well known to pilots, and FAA guidance presumes pilots will recognize the condition and complete the procedure to counteract it within four seconds..[659] But stabilizer trim runaway does not provoke the multitude of simultaneous and seemingly unrelated cautions and warnings that accompany erroneous MCAS activation when triggered by a failure of an AOA sensor.[660] Yet, Boeing assumed that pilots would respond to an unexpected MCAS activation as it if were a runaway stabilizer trim event, within four seconds.[661]

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655 Ibid.
656 Ibid.
657 Susan Parson, "A Finesse for Vitesse: Mastering the Maze of V-speeds," *FAA Safety Briefing,* May/June 2015, accessed here: https://www.faasafety.gov/files/notices/2015/Nov/V_Speed_Review.pdf
658 Ibid.
659 "Approval of Flight Guidance Systems," Advisory Circular (AC) 25.1329-1C, Federal Aviation Administration (FAA), U.S. Department of Transportation (DOT), October 27, 2014, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C_CHG_1_.pdf
660 JATR Report, p. 16 and p. 27.
661 Ibid.

The National Transportation Safety Board found that Boeing, in making this assumption:

> ….did not evaluate all the potential alerts and indications that could accompany a failure that also resulted in uncommanded MCAS operation. Therefore, neither Boeing's system safety assessment nor its simulator tests evaluated how the combined effect of alerts and indications might impact pilots' recognition of which procedure(s) to prioritize in responding to an unintended MCAS operation caused by an erroneous AOA input.[662]

However, according to the JATR "[n]o studies were found that substantiate the FAA guidance concerning pilot recognition time and pilot reaction time . . . . It is not clear on what the FAA guidance concerning pilot recognition time and pilot reaction time was based." [663]

National Transportation Safety Board
September 18, 2019

"WHILE BOEING CONSIDERED THE POSSIBILITY OF UNCOMMANDED MCAS OPERATION AS PART OF ITS FUNCTIONAL HAZARD ASSESSMENT, IT DID NOT EVALUATE ALL THE POTENTIAL ALERTS AND INDICATIONS THAT COULD ACCOMPANY A FAILURE THAT ALSO RESULTED IN UNCOMMANDED MCAS OPERATION."

The JATR also noted that "[a]nalysis of aviation accidents demonstrates that pilots may take a significantly longer time to recognize a malfunction and respond to it than the test flight guidance suggests" and that "[t]he FAA's guidance concerning pilot reaction time of 3 seconds may not be appropriate[.]"[664]

In addition, according to the NTSB, "Multiple alerts and indications can increase pilots' workload, and the combination of the alerts and indications did not trigger the accident pilots to immediately perform the runaway stabilizer procedure during the initial automatic AND stabilizer trim input."[665] The NTSB examined the two accident flights on Lion Air and Ethiopian Airlines as well as the pre-accident flight on Lion Air when MCAS activated, but the plane landed safely. According to the NTSB:

> In all three flights, the pilot responses differed and did not match the assumptions of pilot responses to unintended MCAS operation on which Boeing based its hazard classifications within the safety assessment and that the FAA approved and used to ensure the design safely accommodates failures. Although a number of factors, including system design, training, operation, and the pilots' previous experiences, can affect a human's ability to recognize and take

[662] "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, accessed https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf.
[663] JATR Report, p. 15.
[664] JATR Report, pp. 15-16.
[665] "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, p. 7, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf

> immediate, appropriate corrective actions for failure conditions, industry experts generally recognize that an aircraft system should be designed such that the consequences of any human error are limited.[666]

The NTSB report also found: "While Boeing considered the possibility of uncommanded MCAS operation as part of its functional hazard assessment, it did not evaluate all the potential alerts and indications that could accompany a failure that also resulted in uncommanded MCAS operation. Therefore, neither Boeing's system safety assessment nor its simulator tests evaluated how the combined effect of alerts and indications might impact pilots' recognition of which procedure(s) to prioritize in responding to an unintended MCAS operation caused by an erroneous AOA input."[667] NTSB pointed out that according to Federal regulations under 14 CFR 25.1309(d)(4), "compliance demonstration as part of aircraft certification must include analysis that considers the crew warning cues, corrective action required, and the capability of detecting faults."[668]

Catastrophic Consequences

Despite that, the Committee's investigation also discovered that Boeing was aware, early on in the 737 MAX program, that it could take some pilots 10 seconds or longer to respond to runaway stabilizer trim or uncommanded MCAS activation. Boeing also knew that its own test pilot who took more than 10 seconds to respond to an uncommanded MCAS activation in a fight simulator and found the condition "catastrophic[.]"[669] The FAA defines catastrophic as, "Failure conditions that are expected to result in multiple fatalities of the occupants, or incapacitation or fatal injury to a flight crewmember normally with the loss of the airplane."[670]

The first reference the Committee found to the catastrophic consequences of the Boeing test pilot's 10 second reaction time dates to November 1, 2012, when a Boeing engineer in the 737 MAX Aerodynamic Stability & Control Group emailed his colleagues to discuss recent simulator assessments regarding a stab trim runaway during a wind up turn.[671] In the simulator tests one Boeing pilot, with the assistance of "teamwork," was able to recognize and react to this condition in approximately four seconds.[672] The other pilot, however, found the condition "catastrophic."[673] "The reaction time was long (>10 second) to use the aislestand (sic) stab cutout switch and there was less teamwork with applying the nose up mechanical trim," wrote the engineer.[674]

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666 Ibid.
667 Ibid. at p. 8.
668 Ibid. at p. 8.
669 Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
670 "System Safety Analysis and Assessments for Part 23 Airplanes," FAA Advisory Circular, AC No: 23 .1309-1E, Federal Aviation Administration, November 17, 2011,at p. 11, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC%2023.1309-1E.pdf
671 Boeing internal email from Boeing engineer to two Boeing test pilots, Subject: MCAS Hazard Assessment, November 1, 2012, BATES Number TBC T&I 131226-131227(On file with the Committee).
672 Ibid.
673 Ibid.
674 Boeing internal email from Boeing engineer to two Boeing test pilots, Subject: MCAS Hazard Assessment, November 1, 2012, BATES Number TBC T&I 131226-131227 (On file with the Committee).

The Boeing engineer asked a series of questions in the email that became extremely relevant after the Lion Air and Ethiopian Airlines crashes. As in several other cases, the Committee found Boeing engineers asked the right questions concerning key details, but they were inadequately resolved or dismissed by some of their colleagues. If these crucial questions had been more thoroughly addressed at the time, they could have helped, in some cases potentially dramatically, to improve the safety of the 737 MAX.

Specifically, the Boeing employee asked his colleagues:

> Do you think that with pilot training/knowledge of the [MCAS] system there will be a sufficiently quick response to the stab runaway during the windup turn/recovery and that it is appropriate to deem it hazardous and have the MCAS system designed to meet this? Or should we step up to catastrophic with the assumption that not all pilots will recognize it quickly enough?[675]

That was a revelatory observation. On each of the doomed MAX flights a cacophony of alerts and warnings were erupting on the flight deck in the minutes prior to the crashes. A combination of issues led to the Lion Air and Ethiopian Airlines crashes, but confusion on the flight deck played a key factor in both accidents.[676]

Despite the fact that Boeing knew that the consequences could be "catastrophic" if a pilot did not react quickly enough to uncommanded MCAS activation, and the fact that Boeing cited this fact repeatedly over the years in their internal coordination sheets on MCAS, based on their own internal test data, no one at Boeing apparently informed the FAA about this critical data.[677] Between 2015 and 2018 Boeing issued six separate coordination sheets on MCAS that referenced the "catastrophic" consequences of a greater than 10-second pilot response time.[678] At least four Boeing

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[675] Ibid.

[676] "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, p. 8, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf

[677] Email from Boeing attorney to Committee staff, February 10, 2020, 10:42 PM (On file with the Committee).

[678] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 - TBC T&I 191232 at TBC T&I 191231 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision C, October 19, 2015, TBC

ARs, reviewed, prepared, approved and/or were copied on these coordination sheets.[679] The Committee has been unable to find any indication that any of these ARs informed the FAA about this critical test data. Moreover, Boeing has informed the Committee that it has been unable to locate any record showing that any of these coordination sheets were shared with the FAA.[680]

The language throughout the years in the Boeing coordination sheets remained virtually unchanged regarding the consequences of the 10-second pilot reaction time. It said:

> Stabilizer runaways to pilot reaction (item D) were performed. These failures were arrested by use of the aisle stand cutout switch when the pilot recognized and reacted to the runaway. Assessments were done during WUTs only i.e. within the operational flight envelope, but not assessed by mistrim trim dive recoveries (normal operating envelope). With pilot training to recognize the runaway and use of teamwork, the failure was found Hazardous, which is the same as the item C finding. A typical reaction time was observed to be approximately 4 seconds. A slow reaction time scenario (>10 seconds) found the failure to be catastrophic due to the inability to arrest the airplane overspeed.[681]

Boeing MCAS Coordination Sheets 2015-2018

"A SLOW REACTION TIME SCENARIO (>10 SECONDS) FOUND THE FAILURE TO BE CATASTROPHIC DUE TO THE INABILITY TO ARREST THE AIRPLANE OVERSPEED."

Boeing produced two of these coordination sheets in 2015, two in 2016, and one in 2017. It is notable that Boeing also produced an updated coordination sheet on June 11, 2018, more than one year after the 737 MAX had been certified by the FAA and was already flying in commercial service, and the assessment of a pilot taking more than 10-seconds to react to uncommanded MCAS activation remained unchanged.[682] Yet the FAA, as well as MAX pilots and airlines that purchased the 737 MAX aircraft were unaware of Boeing's findings regarding the catastrophic consequences of a greater than 10-second reaction time to uncommanded

T&I 253262 - TBC T&I 253268 at TBC T&I 253267 (On file with the Committee); and Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision E, July 5, 2016, TBC T&I 129776 - TBC T&I 129782 at TBC T&I 129782 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision F, December 20, 2017, TBC T&I 037449 - TBC T&I 037457 at TBC T&I 037457 (On file with the Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[679] Ibid.

[680] Email from Boeing attorney to Committee staff, February 10, 2020, 10:42 PM. (On file with the Committee).

[681] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," October 19, 2015, TBC-T&I 253262 - TBC-T&I 253268 at TBC-T&I 253262 at TBC-T&I 253267. (On file with the Committee).

[682] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

MCAS activation—and the fact that Boeing's own test pilot failed to respond quickly enough in a flight simulator—as far as the Committee is aware.

Even the most senior leadership of Boeing's 737 MAX program were unaware of the 10-second reaction time issue. In transcribed interviews with Committee staff in April 2020, Michael Teal, the former Chief Project Engineer on the 737 MAX program, said he only learned of the 10-second reaction time issue as part of his preparation for the Committee's interview.[683] Keith Leverkuhn, the former 737 MAX Vice President and General Manager, told Committee staff that he also was unaware of the 10-second reaction time evidence that Boeing had at the time, but deflected his response regarding whether Boeing had an obligation to share this information with the FAA. He said he did have a general understanding that "if the crew does not react within that period of time to certain nonnormals, that they can be catastrophic."[684]

According to Indonesia's final report on the Lion Air crash, accident investigators testing MCAS in a 737 MAX simulator found that, "after just two activations of MCAS, absent any counter from the pilot, the control column force became 'too heavy' to move."[685] MCAS activated more than 20 times during the roughly six minutes leading up to the Lion Air accident,[686] and MCAS activated four times in the minutes leading up to the Ethiopian Airlines accident.[687]

Boeing had assumed that repetitive MCAS activations would not adversely impact the ability of the MAX pilots to maintain control of the aircraft despite the fact that a Boeing AR raised this question. Boeing "Engineering and Test pilots discussed scenario of repeated unintended MCAS activation during MAX development," according to a December 2018 Boeing presentation to the FAA, "and deemed [it] no worse than single unintended MCAS activation."[688] Those assumptions were proven tragically wrong.

737 MAX Chief Project Engineer Approved MCAS Without Fully Understanding It

Michael Teal, Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, approved the design of MCAS, despite being unaware of basic facts about the system. He was not aware that MCAS relied on a single sensor. He was not aware that MCAS could

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[683] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, Boeing Commercial Airplanes (BCA), May 11, 2020.
[684] Committee staff transcribed interview of Keith Leverkuhn, Vice President and General Manager, 737 MAX, Boeing Commercial Airplanes (BCA), May 19, 2020.
[685] Dominic Gates, Lewis Kamb, "Indonesia's devastating final report blames Boeing 737 MAX design, certification in Lion Air crash," *Seattle Times*, Oct. 24, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/indonesias-investigation-of-lion-air-737-max-crash-faults-boeing-design-and-faa-certification-as-well-as-airlines-maintenance-and-pilot-errors
[686] Sinead Baker, "This timeline shows exactly what happened on board the Lion Air Boeing 737 Max that crashed in less than 13 minutes, killing 189 people," *Business Insider*, Oct. 29, 2019, accessed here: https://www.businessinsider.com/lion-air-crash-timeline-boeing-737-max-disaster-killed-189-2019-10
[687] Oren Libermann, Robyn Kriel and Kaleyesus Bekele, "Boeing CEO 'sorry' for lives lost in 737 MAX accidents," *CNN*, April 5, 2019, accessed here: https://www.cnn.com/2019/04/04/world/ethiopian-airlines-crash-preliminary-report-intl/index.html
[688] "MCAS Development and Certification Overview," Boeing presentation to FAA, December 17, 2018, TBC-T&I 130075– TBC-T&I 130117, at TBC-T&I 130109, accessed at p. 197 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf. The same presentation also noted, at TBC-T&I 130109, that the rationale for that assessment was documented in a pilot meeting summary email on June 22, 2016 but that it was "not documented in formal certification" records.

activate repeatedly, and he was not aware that it had taken Boeing's own test pilot more than 10 seconds to respond to an uncommanded MCAS activation in a flight simulator and the pilot described his experience as "catastrophic." Mr. Teal acknowledged this in a Committee staff interview:

T&I Committee Staff: And just to refresh my recollection, at the time that you approved MCAS, you were not aware that it operated from a single AOA sensor, you were not aware that it could activate repeatedly, and you were not aware that Boeing was aware that if a pilot didn't react in 10 seconds to an MCAS activation the result could be catastrophic.

At the time you signed -- this was all information that you were not aware of when you signed off on MCAS.

Mr. Teal: That is correct.[689]

In the interview, Mr. Teal explained that as the Vice President and Chief Project Engineer of the 737 MAX program, he was "responsible for the requirements, the configuration, the design, the testing, the certification and overseeing of any issues in the build process, mainly the engineering work."[690] Yet, while serving in that position, "no employees actually report[ed] to me. …. no engineers directly report[ed] to me," he said. "They all are functionally aligned to the engineering leaders of the company."[691] According to Mr. Teal, the structural engineers reported to the lead of the structural engineering Integrated Product Team (IPT) and the propulsion experts reported up through the propulsion IPT leader, for example. "But from a daily direction and overseeing of the program, you know," Mr. Teal said, "you could say that none of them worked for me but all of them worked for me, is what I like to say."[692]

That organizational structure seems to have both dampened internal oversight at Boeing and diminished accountability regarding Boeing's 737 MAX program, particularly among its most senior leaders. To thank Mr. Teal for his leadership of the 737 MAX program and for helping to keep the program on schedule, Mr. Teal received a bonus in the form of restricted Boeing stock shares after the first flight of the 737 MAX in January 2016.[693] He now serves as the Vice President and Chief Project Engineer of Boeing's 777X program.

Pilots Uninformed About MCAS, References Removed

Boeing not only discounted concerns from its own engineers that in hindsight proved remarkably pertinent to improving the safety of the 737 MAX, but it also did not share certain

[689] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, Boeing Commercial Airplanes (BCA), May 11, 2020.
[690] Ibid.
[691] Ibid.
[692] Ibid.
[693] Ibid.

information about what it knew about MCAS with— regulators, and it chose not to inform the vast majority of MAX pilots about the very existence of MCAS. The unions representing pilots at American Airlines and Southwest Airlines, both of which operate the 737 MAX, allege their members were not made aware of MCAS and the system's ability to command the 737 MAX into a dive until after the Lion Air crash. Captain Dan Carey, then-President of the Allied Pilots Association, which represents American Airlines pilots, testified before the Subcommittee on Aviation in June 2019 that, "[t]he huge error of omission was the fact that Boeing failed to disclose the existence of the MCAS system to the pilot community around the world."[694] The Southwest Airlines Pilots Association has sued Boeing over the omission.[695]

However, the Committee's investigation discovered that Southwest Airlines was made aware of the existence, and purpose of, MCAS on the 737 MAX.[696] Nevertheless, this information was not shared with MAX pilots, and references to MCAS were eventually removed from 737 MAX related documents provided to air carriers, including Southwest Airlines, at Boeing's request.

In July 2014, before efforts to remove that material took place, Mark Forkner, the 737 Chief Technical Pilot at Boeing, and a colleague, gave a 75-page presentation to Southwest Airlines that was labeled: "737-8 MAX Flight Crew Training (For Southwest Airlines internal use only)."[697] Two slides gave a description of MCAS describing its purpose and operating envelope. Among other things, the slides explained that MCAS "[a]ugments pitch stability at high angles-of-attack," that it is "[r]equired to maintain compliance to FAA Certification requirements," that it "[o]perates outside of normal operating envelope," and that it is "[d]isabled with autopilot engaged."[698]

The presentation also indicated, "MCAS autonomously inputs nose down stabilizer when angle-of-attack trigger is exceeded;" "MCAS is not active during normal operation; Operates near stall;" "MCAS produces maneuvering characteristics similar to 737-800;" and "Small amount of trim wheel movement during MCAS activity."[699] It is important to note, however, that this was two years prior to the redesign of MCAS which expanded its range and granted it greater authority.

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[694] Testimony of Dan Carey, then-President of Allied Pilots Association, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," House Committee on Transportation and Infrastructure Subcommittee on Aviation, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, p. 18, accessed here: https://transportation.house.gov/imo/media/doc/CA%20Carey%20Hearing%20testimony%20.pdf); see also *Southwest Airlines Pilots Ass'n v. The Boeing Co.*, Case No. DC-19-16290 (Dist. Ct. for Dallas County, Texas), Plaintiff's Original Petition, at 2 (Oct. 7, 2019) (alleging, in part, that "Boeing made a calculated decision to rush a re-engined aircraft to market to secure its single-aisle market share and prioritize its bottom line. In doing so, Boeing abandoned sound design and engineering practices, withheld safety critical information from regulators and deliberately mislead [sic] its customers, pilots and the public about the true scope of design changes to the 737 MAX."), accessed here: https://swaparesources.s3-us-west-2.amazonaws.com/assets/pdf/Communication/Complaint_Against_Boeing_(2).pdf

[695] David Koenig, "Southwest pilots' union sues Boeing over grounding of plane," *Associated Press* (AP), October 7, 2019, accessed here: https://apnews.com/b07e9d1121b34a0f884d6626c07fa876; see also *Southwest Airlines Pilots Ass'n v. The Boeing Co.*, Case No. DC-19-16290 (Dist. Ct. for Dallas County, Texas), Plaintiff's Original Petition, Oct. 7, 2019, accessed here: https://swaparesources.s3-us-west-2.amazonaws.com/assets/pdf/Communication/Complaint_Against_Boeing_(2).pdf

[696] Manager, 737MAX/777X FT Development and 737 MAX Chief Technical Pilot, "737-8 MAX Flight Crew Training, (For Southwest Airlines internal use only), July 24, 2014, TBC T&I 447158, TBC T&I 447203-447204. (On file with the Committee).

[697] Ibid.

[698] Ibid.

[699] Ibid.

The redesign of MCAS, which was approved in March 2016, also coincided with Boeing's efforts to remove MCAS from pilot training materials for its MAX customers. In a March 30, 2016, email, Mr. Forkner assured an FAA official that references to MCAS could be deleted from the official FCOM and other 737 MAX training documents because MCAS is "completely transparent to the flight crew and only operates WAY outside of the normal operating envelope."[700] The FAA ultimately permitted Boeing to remove references to MCAS.

According to internal Boeing emails, Mr. Leverkuhn approved of the redesign of MCAS in March 2016, expanding the range of flight conditions in which MCAS could operate to enable it to activate at lower speeds.[701] However, Mr. Teal acknowledged in his interview with Committee staff that he authorized the redesign of MCAS as well.[702]

In any event, on March 30, 2016, just a few hours after approval was given to redesign MCAS, Boeing requested permission from FAA to remove references to MCAS from the FCOM.[703] Mr. Leverkuhn said that he "was not aware" at the time that Mr. Forkner was making a request to the FAA to remove references to MCAS from the FCOM.[704] Asked (1) if he was aware that Mark Forkner was planning to make this request to the FAA, (2) when he first learned of this request being made, (3) whether he was told in advance this request might be made, or (4) if he was aware of the request to remove MCAS from the FCOM prior to the meeting that approved the redesign of MCAS—Mr. Teal responded "I don't recall" to all four questions.[705]

The Committee staff did not find evidence as to whether Mr. Forkner was specifically informed about the redesign of MCAS at the time. Both Mr. Leverkuhn and Mr. Teal said that they believed Mr. Forkner, and the team of technical pilots he led, should have been informed about their approval to redesign MCAS, but they are not certain if this information was shared with him or not.[706] The Committee was unable to interview Mr. Forkner as part of our investigation. The Committee also sought to interview several other individuals who had previously served in senior positions at the FAA but was unsuccessful.[707]

MCAS Did Not Meet Its Own Design Requirements

On top of all of the other issues surrounding MCAS and the questions from Boeing's own engineers that appear to have not been thoroughly addressed, MCAS also failed to meet several of

[700] Email from Mark Forkner to FAA, "MCAS Lives in Both FCCs," March 30, 2016.
[701] Internal Boeing email, "Subject: 5-15 update," April 1, 2016, 3:28 p.m., BATES Number TBC T&I 255562. (On file with the Committee).
[702] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, May 11, 2020.
[703] Internal Boeing email, "Subject: 5-15 update," April 1, 2016, 3:28 p.m., BATES Number TBC T&I 255562. (On file with Committee); Email from Mark Forkner to FAA, "Subject: MCAS lives in both FCCs," March 3, 2016 (On file with the Committee).
[704] Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager, 737 MAX, Boeing Commercial Airplanes (BCA), May 19, 2020.
[705] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, May 11, 2020.
[706] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, May 11, 2020. Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager, 737 MAX, Boeing Commercial Airplanes (BCA), May 19, 2020.
[707] This included, John S. Duncan, former Deputy Associate Administrator for Aviation Safety and former Executive Director of the FAA's Flight Standards Service; Dorenda Baker, former Director of the Aircraft Certification Service (AIR), and Margaret "Peggy" Gilligan, former FAA Associate Administrator for Aviation Safety.

Boeing's own design requirements on certain issues. According to the Boeing Coordination Sheets regarding MCAS, the Aerodynamics Stability & Control Requirements included:

> "MCAS shall not have any objectionable interaction with the piloting of the airplane."[708]
>
> "MCAS shall not interfere with dive recovery."[709]

In both the Lion Air and Ethiopian Airlines accidents MCAS failed to meet these design requirements. At the Committee's October 30, 2019, 737 MAX hearing, John Hamilton, then-Chief Engineer for the Boeing Commercial Airplanes division, acknowledged that at least one of these requirements was not met in response to a question from Representative Greg Stanton.

> Mr. HAMILTON. When the MCAS wasn't trimmed out, as we assumed it would be, it caused the airplane to go into a dive that the crews were not able to recover from.
>
> Mr. STANTON. Mr. Hamilton, was MCAS a contributing factor into the dive, as noted in the final accident report released by Indonesian investigators?
>
> Mr. HAMILTON. Yes.[710]

In short, MCAS was poorly designed, not adequately tested, and received flawed oversight by the FAA. Greg Travis, the software engineer and private pilot who wrote about MCAS in the IEEE's *Spectrum* magazine last year put the Boeing design and development process in stark terms:

> Boeing produced a dynamically unstable airframe, the 737 Max. That is big strike No. 1. Boeing then tried to mask the 737's dynamic instability with a software system. Big strike No. 2. Finally, the software relied on systems known for their propensity to fail (angle-

[708] Boeing Coordination Sheet March 30, 2016 in House Committee on Transportation and Infrastructure hearing record, "The Boeing 737 MAX: Examining the Design, Development and Marketing of the Aircraft," October 30, 2019, p. 161, accessed at: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Boeing Coordination Sheet June 11, 2018 in House Committee on Transportation and Infrastructure Hearing record, "The Boeing 737 MAX: Examining the Design, Development and Marketing of the Aircraft," October 30, 2019, p. 170 accessed at: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[709] Boeing Coordination Sheet March 30, 2016 in House Committee on Transportation and Infrastructure hearing record, "The Boeing 737 MAX: Examining the Design, Development and Marketing of the Aircraft," October 30, 2019, p. 162 accessed at: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Boeing Coordination Sheet June 11, 2018 in House Committee on Transportation and Infrastructure Hearing record, "The Boeing 737 MAX: Examining the Design, Development and Marketing of the Aircraft," October 30, 2019, p. 170 accessed at: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[710] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 80 accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

> of-attack indicators) and did not appear to include even rudimentary provisions to cross-check the outputs of the angle-of-attack sensor against other sensors, or even the other angle-of-attack sensor. Big strike No. 3. None of the above should have passed muster.[711]

Despite that assessment, the two most senior Boeing officials on the 737 MAX program were both extraordinarily reluctant to acknowledge any missteps or mistakes in the development of the 737 MAX aircraft. In an interview with Committee staff, Michael Teal, the former 737 MAX Vice President, Chief Project Engineer and Deputy Program Manager, said: "We believed that we have a safe aircraft as designed, as intended, and put out with the designs and training associated with it."[712] Mr. Teal defended Boeing's work by saying the company followed its process. For example:

> **T&I Committee Staff:** [B]ecause you followed the process, your testimony is that the 737 MAX was safe when it was certified.
>
> **Mr. Teal:** My testimony, that by defining and delivering and certifying the aircraft, it has been determined as safe. That is the process we worked through.[713]

The responses the Committee has received from senior Boeing officials about MCAS and the now well-documented technical flaws, management failures, and multiple missed opportunities to correct the tragic path that MCAS took, and its contribution to two fatal MAX crashes has been disturbing because of the clear resistance to acknowledge any technical gaffes or managerial miscalculations on the part of Boeing that now seem blatantly obvious and abundantly clear to anyone that looks. Unfortunately, MCAS was not the only component on the 737 MAX that had problems.

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[711] Gregory Travis, "How the Boeing 737 Max Disaster Looks to a Software Developer," *IEEE Spectrum*, April 18, 2019, accessed here: https://spectrum.ieee.org/aerospace/aviation/how-the-boeing-737-max-disaster-looks-to-a-software-developer

[712] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, May 11, 2020.

[713] Ibid.

6. AOA Disagree Alert

-AOA Disagree Alert-

INVESTIGATIVE FINDINGS

- Boeing has publicly blamed its software supplier, a company now known as Collins Aerospace Systems, for tying the AOA Disagree alert, which was supposed to be a standard feature on all 737 MAX aircraft, to an optional AOA Indicator display[714]—the result of which rendered the AOA Disagree alert inoperable on more than 80 percent of the MAX aircraft. However, the Committee's investigation found that in July 2015, Boeing tested this software and failed to detect the problem.[715] Ultimately, Boeing did not publicly acknowledge that the AOA Disagree alerts on more than 80 percent of the 737 MAX fleet were inoperative until ***after*** the Lion Air crash in October 2018.[716]

- In August 2017, three months after the 737 MAX entered revenue service, Boeing issued a new problem report[717] solely to its software supplier establishing that the 737 MAX's AOA Disagree alert was tied to the optional AOA Indicator display and therefore was not functioning on the vast majority of the 737 MAX fleet worldwide.[718]

- Rather than immediately informing the FAA about the inoperable AOA Disagree alert and advising Boeing to fix the problem as soon as possible, a Boeing Authorized Representative

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[714] The Boeing Company, Press Statement, "Boeing Statement on AOA Disagree Alert," May 5, 2019, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431 (Hereafter referred to as "Boeing Statement on AOA Disagree Alert).

[715] "AOA DISAGREE Displayed with AOA Fail Flag," Problem Report (PR) 195, PR opened: May 14, 2015, PR closed: July 29, 2015, BATES Number TBC T&I TBC 267345-267346 and BATES Number COLLINS_00075 - COLLINS_00076. (On file with the Committee). (Hereafter referred to as "AOA Disagree Alert Problem Report #195").

[716] Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty See also Boeing Statement on AOA Disagree Alert, and Boeing AOA Disagree Alert Narrative at TBC-T&I 267830 - TBC-T&I 267831 (On file with the Committee).

[717] Problem reports are routinely used in the software development and quality assurance process to define, analyze and resolve software related problems. See: "Software Problem Report," QA Platforms, March 9, 2019, accessed here: https://qa-platforms.com/software-problem-report-spr. Various FAA records document how to maintain a proper problem reporting system, such as "Software Approval Guidelines," Federal Aviation Administration (FAA), Order 8110.49, CHG 2, accessed here: https://www.faa.gov/documentLibrary/media/Order/FAA_Order_8110.49_with_chg_2.pdf and "Safety Issues and Shortcomings With Requirements Definition, Validation, and Verification Processes Final Report," DOT/FAA/TC-16/39, December 2016, accessed here: https://www.faa.gov/aircraft/air_cert/design_approvals/air_software/media/TC-16-39.pdf

[718] Boeing AOA Disagree Alert Narrative. BATES Number TBC-T&I 267826 – TBC-T&I 267833 at TBC-T&I 267830 (hereafter referred to as "Boeing AOA Disagree Alert Narrative") (On file with the Committee); and Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," Bloomberg, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty. Requirements Definition, Validation, and Verification Processes Final Report," DOT/FAA/TC-16/39, December 2016, accessed here: https://www.faa.gov/aircraft/air_cert/design_approvals/air_software/media/TC-16-39.pdf

[718] Boeing AOA Disagree Alert Narrative. BATES Number TBC-T&I 267826 – TBC-T&I 267833 at TBC-T&I 267830, (Hereafter referred to as "Boeing AOA Disagree Alert Narrative").

INVESTIGATIVE FINDINGS – Continued

- (AR) consented to Boeing's plan to postpone a software update to fix the problem until 2020, nearly three years later, so it could be done in conjunction with the planned rollout of the MAX-10 aircraft.[719] This decision to defer the fix to 2020 was made in September 2017.[720]

- Boeing's August 2017 problem report said: "explain how communicated to operators FTD," implying that Boeing intended to inform its customer airlines of the AOA Disagree alert issue via a Fleet Team Digest (FTD). In fact, Boeing ultimately prepared a FTD. Inexplicably, they never sent it keeping their customers in the dark about this issue.[721]

- On August 16, 2018, Boeing produced a Flight Crew Operations Manual (FCOM) for Lion Air's MAX aircraft that contained a description and graphic of a functioning AOA Disagree alert, despite the fact that Boeing had known for one year that it was not functioning on the majority of the 737 MAX fleet, including Lion Air's purchased MAX aircraft.[722]

- The non-functioning AOA Disagree alert was one of three missed opportunities to discover that an AOA sensor on the aircraft that would become Lion Air flight 610 was faulty before flight 610 departed. Testing at Xtra Aerospace could have discovered the AOA sensor's mis-calibration before the refurbished part was cleared for return to service.[723] The mis-calibration could also have been caught when the part was installed on Lion Air's aircraft in Denpasar.[724] Third, a properly functioning AOA Disagree alert could have alerted Lion Air's Jakarta-bound flight crew, and ultimately aircraft maintenance, that there was a potential problem with an AOA sensor before the aircraft was used for Lion Air flight 610.[725]

- The AOA Disagree alert was not considered a safety-critical component by either Boeing or the FAA. However, in July 2019, then-Acting FAA Administrator Dan Elwell informed the Committee that "[a]lthough an AOA disagree message was not necessary to meet FAA safety regulations, once it was made part of the approved type design, it was required to be installed and functional on all 737 MAX airplanes Boeing produced."[726]

[719] Boeing AOA Disagree Alert Narrative at TBC-T&I 267830 - TBC-T&I 267831.
[720] "737-7/-8/-9 MAX Display System MDS Certification Summary," Document Number D242A408, Release/Revision F, September 8, 2017, BATES Number TBC T&I 267387-267678, at TBC T&1 267617, pp. 1, 231, (AOA Disagree Annunciation) (On file with the Committee).
[721] "AOA DISAGREE Annunciation," Problem Report (PR) 693, PR opened: August 10, 2017, PR closed: February 1, 2019, BATES Number TBC-T&I 267363-267365 at TBC-T&I 267365 and BATES Number COLLINS_00014 - COLLINS_00016. (On file with the Committee). (Hereafter referred to as "AOA Disagree Alert Problem Report #693"). See also AOA Disagree Alert Narrative at TBC-T&I 267831
[722] 737-8 Flight Crew Operations Manual, P. T. Lion Mentari, August 16, 2018, accessed at pp. 175-177 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf. See also Boeing Statement on AOA Disagree Alert and Boeing AOA Disagree Alert Narrative at TBC-T&I 267830 - TBC-T&I 267831 (On file with the Committee).
[723] Lion Air Flight 610 Final Aircraft Accident Investigation Report, p. xviii, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf
[724] Ibid.
[725] Ibid., p. 178, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf
[726] Letter from then-Acting FAA Administrator Dan Elwell to Chair Peter DeFazio, regarding the mandatory installation of functional AOA Disagree alerts on all Boeing 737 MAX aircraft, July 11, 2019 (On file with the Committee).

INVESTIGATIVE FINDINGS - Continued

- Boeing has maintained it appropriately deferred the fix to the AOA Disagree alert because an inoperable alert did not lessen safety. The company also asserted that Boeing's senior leadership only became aware of the non-functioning AOA Disagree alert issue after the Lion Air crash.[727] At the same time, Boeing has said that multiple company officials, including systems engineers, pilots, and crew operations specialists—as well as an AR—reviewed the issue in 2017.[728] Yet Boeing continued to produce and deliver its MAX aircraft to customers before the Lion Air crash knowing the AOA Disagree alert was inoperable on most 737 MAX aircraft without informing them of this non-functioning component.

- As far as the Committee is aware, the FAA has so far failed to hold Boeing accountable for its lack of transparency regarding the AOA Disagree alert and the fact that Boeing knowingly continued to manufacture and deliver MAX aircraft with inoperative AOA Disagree alerts, which did not conform to the MAX's FAA approved type certificate.

- The AOA Disagree alert issue may not rise to what Boeing and the FAA believe are critical safety issues. However, the Committee's investigation has found that it sheds light on a broader cultural issue within Boeing regarding business decisions the company makes when it is forced to confront ethical issues impacting its customers.

Angle of Attack (AOA) Disagree Alert and AOA Indicator

An airplane's angle of attack (AOA) refers to the angle between an airplane's wings and the oncoming air during flight.[729] AOA sensors or vanes, located on the outside of both sides of the flight deck[730] on the 737 MAX, gather this data, which feeds into various indications, cautions, and warnings to the flight crew, as well as automated functions. Most importantly, when the AOA vanes detect a critically high AOA, the airplane's computers activate a "stick shaker" and associated stall warnings to inform the flight crew that the airplane is approaching an aerodynamic stall, or a loss of lift because the air can no longer flow across the wings undisturbed.[731]

In the case of the 737 MAX, the AOA Disagree alert is a feature on the flight display that illuminates if the left or right angle of attack sensors disagreed by more than 10 degrees, for more than 10 continuous seconds.[732] This safeguard and redundancy was utilized due to the fact that angle

[727] Boeing Statement on AOA Disagree Alert.
[728] Boeing AOA Disagree Alert Narrative at TBC-T&I 267830 (On file with the Committee).
[729] See: "What is Angle of Attack?" *AERO*, October 2000, The Boeing Company, accessed here: http://www.boeing.com/commercial/aeromagazine/aero_12/whatisaoa.pdf and "Angle of Attack (AOA) Systems," April 2018, UTC Aerospace Systems, accessed here: https://utcaerospacesystems.com/wp-content/uploads/2018/04/Angle-of-Attack-AOA-Systems.pdf
[730] "Flight deck" is the more modern term for a "cockpit." According to Aviation Stack Exchange, "A cockpit is a hole with a seat that you strap into for the entire flight. A flight deck is a larger version of a cockpit, where you can at least leave your seat and walk behind it." See: https://aviation.stackexchange.com/questions/66094/cockpit-vs-flight-deck#:~:text=A%20cockpit%20is%20a%20hole,the%20top%20of%20the%20ship
[731] "Stall Warning Systems," Skybrary, accessed here: https://www.skybrary.aero/index.php/Stall_Warning_Systems
[732] Boeing AOA Disagree Alert Narrative at TBC-T&I 267826 (On file with the Committee).

of attack sensors have been known to fail and to provide faulty data.[733] Starting in 2006, the AOA Disagree alert became a standard feature on the 737 NG and subsequently on the 737 MAX.[734] Boeing implemented it as a standard feature on the 737 NG in response to a customer request.[735]

Some aircraft are also equipped with an AOA Indicator. This indicator is a dial in the upper right-hand corner of the flight display that shows the airplane's raw angle of attack data.[736] It offers a visual indication of the amount of lift the wings are generating, thereby helping the flight crew avoid a critically high AOA and, ultimately, a stall.[737]

On the 737 MAX, while an AOA Indicator was an extra option that could be purchased on the aircraft, less than 20 percent of MAX airplanes delivered before the Lion Air crash had an AOA Indicator installed.[738] Since 1999, in response to requests from two separate Boeing customers, the AOA Indicator has been available as an optional display feature on the MAX's predecessor aircraft, the 737 NG, and this option carried over to the 737 MAX.[739]

How the AOA Disagree Alert Became Non-Functioning on the 737 MAX

In the case of the 737 MAX, Boeing used a supplier to code the software for the AOA Disagree alert by following Boeing's Specification Control Drawing (SCD) for the alert. At the time, the supplier traded as Rockwell Collins (Collins), though today the company does business as Collins Aerospace Systems (Collins Aerospace).[740] In essence, the software was responsible for taking the inputs provided by the two AOA sensors on the left and right sides of the aircraft, and then computing an angle of attack indication. But how that indication would be used was a subject of confusion between Boeing and Collins.

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[733] See: Alan Levin and Ryan Beene, "Sensors Linked to Boeing 737 Crashes Vulnerable to Failure," *Bloomberg*, April 10, 2019, accessed here: https://www.bloomberg.com/news/articles/2019-04-11/sensors-linked-to-737-crashes-vulnerable-to-failure-data-show and Curt Devine and Drew Griffin, "Boeing relied on single sensor for 737 Max that had been flagged 216 times to FAA," *CNN Investigates*, April 30, 2019, accessed here: https://www.cnn.com/2019/04/30/politics/boeing-sensor-737-max-faa/index.html

[734] Boeing AOA Disagree Alert Narrative at TBC-T&I 267826 and TBC-T&I 267829. (On file with the Committee).

[735] Boeing AOA Disagree Alert Narrative at TBC-T&I 267828. (On file with the Committee).

[736] Boeing AOA Disagree Alert Narrative at TBC-T&I 267826. (On file with the Committee).

[737] See: Rob Mark, "How It Works: Angle of Attack Indicator," *Flying*, June 5, 2017, accessed here: https://www.flyingmag.com/how-it-works-angle-attack-indicator/ and Lisa R. Le Vie, "Review of Research on Angle-of-Attack Indicator Effectiveness, Langley Research Center, Hampton, Virginia, National Aeronautics and Space Administration (NASA), NASA/TM–2014-218514, August 2014, accessed here: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140011419.pdf

[738] Boeing AOA Disagree Alert Narrative at TBC-T&I 267828 - TBC-T&I 267829. (On file with the Committee).

[739] Ibid.

[740] In November 2018, United Technologies Corporation (UTC) acquired Rockwell Collins and took the name Collins Aerospace. See: Woodrow Bellamy III , "UTC Completes Acquisition of Rockwell Collins," *Aviation Today*, November 27, 2018, accessed here: https://www.aviationtoday.com/2018/11/27/utc-completes-acquisition-rockwell-collins. In April 2020, United Technologies Corporation, the parent company of Collins Aerospace merged with Raytheon Corporation forming Raytheon Technologies Corporation. However, its subsidiary Collins Aerospace still maintains that same name. See, "About Us," Collins Aerospace, accessed here: https://www.collinsaerospace.com/en/who-we-are/about-us and Carten Cordell, "Raytheon Completes Merger with United Technologies," *Washington Business Journal*, April 3, 2020, accessed here: https://www.bizjournals.com/washington/news/2020/04/03/raytheon-completes-merger-with-united-technologies.html

6. AOA Disagree Alert

In January 2014, Boeing and Collins engaged in a peer review of the software development, and the result was a Boeing requirement that the AOA Disagree alert **should** be tied to the optional AOA indicator.[741]

In June 2014, Collins conducted an internal review of high-level requirements, and noticed that the requirement to display the AOA Disagree alert was silent on whether or not it should be linked to the AOA Indicator.[742] Collins submitted a change request to Boeing to help clarify this issue.[743]

In November 2014, in response to that change request, Boeing and Collins engaged in another peer review, which concluded with Boeing stating that the AOA Disagree alert should **not** be tied to the optional AOA Indicator.[744]

In January and April of 2015, Collins delivered versions of the software build to Boeing that did **not** tie the AOA Disagree alert to the optional AOA Indicator.[745]

However, in May 2015 Boeing issued a problem report to Collins, concerning the AOA Fail Flag.[746] The problem was that the AOA Disagree alert could be displayed at the same time the AOA Fail Flag appeared on the primary flight display, a condition which should not occur. According to Collins, the Fail Flag, "indicates that there is no valid angle of attack sensor input available on either the pilot's or co-pilot's side."[747] Such invalid data should not be used. Still, because it operated independent of the AOA Indicator, the AOA Disagree alert could receive the faulty input data and incorrectly use it for comparison to input from the opposite AOA sensor. The resulting display of the AOA Disagree alert would be meaningless if that happened.

To fix the issue, on July 14, 2015, Collins updated the AOA Disagree alert logic to validate that the AOA Indicator was displayed before displaying an AOA Disagree alert. This fix, however, effectively tied the display of the AOA Disagree alert back to the display of the optional AOA

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741 Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 8 (On file with the Committee). See also January 2014 Peer Review Report MAXPR-0000148, Finding #54, BATES number COLLINS_00122 – COLLINS_00185 at COLLINS_00173 - COLLINS_00174. (On file with the Committee).

742 Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 5 (On file with the Committee). See also Software High-Level requirements review MDSPR-0000369, finding #3, BATES number COLLINS_00107 - COLLINS_00121 at COLLINS_00109. (On file with the Committee).

743 Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 5 (On file with the Committee). See also PFD SCD Issues found during HL reviews, BATES number COLLINS_00105 (On file with the Committee).

744 Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 6 (On file with the Committee). See also Boeing/Rockwell Collins Peer Review Record MAXPR-00343, finding #7, BATES number COLLINS_00187 - COLLINS_00203 at COLLINS_00195 - COLLINS_00196. (On file with the Committee).

745 Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 8 (On file with the Committee).

746 Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 8 (On file with the Committee). See also 37MAXMDS-S_PR195 (ITRACS PR 195), BATES number COLLINS_00075 - COLLINS_00076 (On file with the Committee).

747 Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 8 (On file with the Committee).

Indicator.[748] This meant that the AOA Disagree alert, although installed in every Boeing 737 MAX airplane, would function **only** on the airplanes that were equipped with the optional AOA Indicator.

Boeing employees "re-tested" the software fix Collins had made and found that the Fail Flag issue had been appropriately "resolved."[749] On July 29, 2015, Boeing closed the problem report and accepted Collins' solution.[750]

No one at Boeing appeared to realize that the fix to the Fail Flag issue had tied the AOA Disagree alert to the AOA Indicator until years later. Boeing did eventually put new processes in place to improve its verification and validation methods as a result of this incident, however.

Discovering the Non-Functioning AOA Disagree Alert

In March 2017, the FAA certified the 737 MAX. In August 2017, three months after airlines had begun flying the MAX in revenue service, Boeing learned through tests it was conducting that the AOA Disagree alert was not functioning on the vast majority of MAX aircraft.[751] The AOA Disagree alert was only operating on aircraft whose owners had also purchased the optional AOA Indicator.[752] Instead of promptly reporting its knowledge of this inoperable alert to the FAA, and telling affected customers and pilots, Boeing chose to postpone the fix for the defect until 2020, nearly three years later.[753] In essence, by its actions, Boeing chose to conceal this fact from the FAA, affected customers, and MAX pilots. Most astoundingly, Boeing continued to manufacture and deliver scores of MAX aircraft with non-functioning AOA Disagree alerts, without informing the FAA, airlines, or pilots about the fact that the alert, though described in technical materials provided to airlines, was not functioning on those airplanes.

Boeing has said none of its senior leadership was aware of the AOA Disagree alert issue at the time.[754] However, multiple Boeing officials were aware of the AOA Disagree alert issue and the decision to postpone fixing it for three years.[755] In addition, no one at Boeing, to the Committee's knowledge, has been held accountable for the company's actions.

Furthermore, according to the FAA, the AOA Disagree alert is required to be installed and functional on all MAX airplanes since it is part of the MAX's approved type design.[756] Despite that, to date the Committee is unaware of the FAA taking any punitive action against Boeing for its handling of the AOA Disagree alert on MAX aircraft.

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[748] Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 9 (On file with the Committee).
[749] Boeing AOA Disagree Problem Report #195, 37MAXMDS-S_PR195, BATES Number COLLINS_0075 – COLLINS_0076 at COLLINS_0076
[750] Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 9 (On file with the Committee). See also 37MAXMDS-S_PR195, BATES number COLLINS_0075 – COLLINS_0076 at COLLINS_0076
[751] Boeing AOA Disagree Alert Narrative at TBC-T&I 267828 - TBC-T&I 267830. (On file with the Committee).
[752] Ibid.
[753] Ibid. at TBC-T&I 267830 - TBC-T&I 267831
[754] Boeing Statement on AOA Disagree Alert.
[755] Boeing Statement on AOA Disagree Alert; Boeing AOA Disagree Alert Narrative at TBC-T&I 267830 (On file with the Committee).
[756] Letter from then-Acting FAA Administrator Dan Elwell to Chair DeFazio, July 11, 2019. (On file with the Committee).

Angle of Attack (AOA) Disagree Alert - Timeline

January 2014	June 2014	November 2014
A Boeing-Collins peer review of the AOA Disagree alert software results in a Boeing requirement that the AOA Disagree alert, a standard feature on all 737 MAX aircraft, should be tied to the optional AOA Indicator.	Collins conducts an internal review of high-level requirements for the AOA Disagree alert but notices it was silent on whether or not the alert should be tied to the AOA Indicator. Collins suggests that a change might be necessary.	A Boeing-Collins peer review concludes with Boeing stating that the AOA Disagree alert should not be tied to the optional AOA Indicator.
January - April 2015	**May 2015**	**July 2015**
Collins delivered various versions of the software to Boeing that did not tie the AOA Disagree alert to the optional AOA Indicator per Boeing's directions.	Boeing issues a "problem report" to Collins concerning the AOA Fail Flag, a separate feature that is tied to the AOA Indicator.	To fix the AOA Fail Flag issue, Collins updated the AOA Disagree alert logic, which resulted in effectively tying the AOA Disagree alert back to the optional AOA Indicator. Boeing tested and accepted this fix without realizing it had re-tied the AOA Disagree alert back to the AOA Indicator.
August 2017	**November 7, 2017**	**October 29, 2018**
During routine tests Boeing realized that the AOA Disagree alert was now tied to the optional AOA Indicator, meaning it only functioned on less than 20 percent of MAX aircraft with the optional AOA Indicator. Boeing issued a new "problem report" to Collins indicating that the AOA Disagree alert should not be tied to the optional AOA Indicator.	At a Collins-Boeing weekly status meeting, Boeing confirmed that it had decided to defer fixing the AOA Disagree alert for three years, until 2020 when the 737 MAX-10 was then expected to enter service. Boeing knowingly continued to both manufacture and deliver aircraft that did not conform to the 737 MAX's FAA approved aircraft type certificate.	Lion Air flight 610 crashes killing 189 people. By the time of the Lion Air crash Boeing had knowingly delivered an estimated 200 737 MAX airplanes to its customers with nonfunctioning AOA Disagree alerts and failed to inform them or the FAA of that fact.
November 6-7, 2018	**May 2019**	**July 11, 2019**
Boeing issues a Flight Crew Operations Manual Bulletin for the 737 MAX, listing the AOA Disagree alert as one of several possible indications of erroneous AOA data, "if AOA indicator option is installed." The FAA issues a similar alert the following day.	After news reports about Boeing delivering aircraft with non-functioning AOA Disagree alerts emerged at the end of April 2019, Boeing issued a statement on its website, which blamed its software supplier for the problem. "The software delivered to Boeing linked the AOA Disagree alert to the AOA Indicator, which is an optional feature on the [737] MAX and the [737] NG."	Then-Acting FAA Administrator writes to Chairs DeFazio and Larsen. "Although an AOA disagree message was not necessary to meet FAA safety regulations, once it was made part of the approved type design, it was required to be installed and functional on all 737 MAX airplanes Boeing produced," it says. The Committee is unaware of any action the FAA has taken to hold Boeing responsible for its actions regarding this matter.

6. AOA Disagree Alert

Both Boeing[757] and the FAA[758] have argued that an AOA Disagree alert is not a safety-critical feature. Boeing has also said that the AOA Disagree alert only "provides the flight crew with supplemental information, not necessary for safety of flight. The alert may direct the crew to primary flight indicators, such as the airspeed and altitude alerts, which direct specific pilot action. The alert itself, however, has never been designed to prompt any specific action by the crew…"[759]

Nevertheless, as Boeing has also acknowledged to the Committee, the AOA Disagree alert "would help in understanding flight deck effects resulting from the undetected failure of an AOA sensor."[760] Both MAX crashes involved faulty AOA input data from the aircraft's AOA sensors.[761]

Pilots flying aircraft with an AOA Disagree alert could rely on this alert, among other indications, to inform them of a failed AOA sensor or flawed AOA data. But pilots flying the 737 MAX would have believed the AOA Disagree alert in their aircraft was functional because, although Boeing knowingly produced 737 MAX airplanes without properly functioning AOA Disagree alerts, Boeing nonetheless described the alert in the flight crew operating manuals provided to airlines for dissemination to their pilots. Boeing knew the alert was not functioning properly and failed to inform their MAX customers that this component was inoperative.

Boeing Employee Email
October 5, 2017

"I STILL THINK WE NEED A BULLETIN TO LET THEM [THE PILOT'S] KNOW WHAT THEY MAY BE MISSING…."

In discussing whether or not to inform 737 MAX pilots about the inoperable AOA Disagree alert through an Operations Manual Bulletin (OMB), one Boeing employee wrote to a colleague on October 5, 2017, "I still think we need a bulletin to let them [the pilots] know what they may be missing…."[762] The employee's colleague responded by recommending Boeing send a Fleet Team Digest, rather than an OMB, because the inoperable AOA Disagree alert was not considered a safety issue and because there are no specific crew procedures to deal with a non-functioning alert.[763] In the end, Boeing never sent either notice to MAX pilots.

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[757] Boeing AOA Disagree Alert Narrative at TBC-T&I 267830. (On file with the Committee).
[758] Testimony of Earl Lawrence, FAA Executive Director of Aircraft Certification, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, p. 46, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf
[759] Boeing AOA Disagree Alert Narrative at TBC-T&I 267829 at (On file with the Committee); See also "Transmittal of Final Decision Safety Review Board SRB Presentation Materials for the Week of December 3, 2018," Letter from Boeing to FAA, December 14, 2018, BATES Number TBC T&I 267686-267814, at TBC T&I 267751-267762 ("Issue Title: Pilot Recognition and Response to AoA Disagree without Flight Deck Indication," Safety Review Board, December 6, 2018) (On file with the Committee).
[760] Boeing AOA Disagree Alert Narrative at TBC-T&I 267828.
[761] See: Dominic Gates, "Pilots struggled against Boeing's 737 MAX control system on doomed Lion Air flight," *Seattle Times*, November 27, 2018, accessed here: https://www.seattletimes.com/business/boeing-aerospace/black-box-data-reveals-lion-air-pilots-struggle-against-boeings-737-max-flight-control-system and Chris Loh, "Ethiopia Reveals Initial Boeing 737 MAX Crash Findings," *Simple Flying*, March 9, 2020, accessed here: https://simpleflying.com/ethiopia-boeing-737-max-crash-findings
[762] Internal Boeing Email, "Subject: RE New ops bulletins," October 5, 2017, 1:50 PM, BATES Number TBC T&I 267376-267382, at TBC T&I 267377. (On file with the Committee).
[763] Ibid. at TBC T&I 267376.

The Indonesian authority's final report on the Lion Air crash also concluded that this lack of information and lack of a functioning AOA Disagree alert reduced the flight crew's situational awareness.[764]

Moreover, in a July 11, 2019, written response to Chair DeFazio and Subcommittee on Aviation Chair Larsen, then-Acting FAA Administrator Elwell explained that the AOA Disagree alert was required to be installed and functional on MAX aircraft regardless of whether or not it was deemed safety-critical:

> Once certified by the FAA, *all* features included on the airplane become part of the certified type design or approved type design. These features are mandatory in each airplane produced to that type design thereafter, whether or not they are required for safety. … Although an AOA disagree message was not necessary to meet FAA safety regulations, once it was made part of the approved type design, it was required to be installed and functional on all 737 MAX airplanes Boeing produced.[765]

Boeing's Lack of Transparency Regarding the AOA Disagree Alert

In August 2017, upon discovering the AOA Disagree alert on 737 MAX aircraft was only functioning on aircraft for which owners had purchased an optional AOA Indicator,[766] Boeing issued a problem report to Collins Aerospace.[767] Boeing also conducted an internal review to determine if the defect rendered the airplane unsafe, and if it could defer fixing the defect until a later date.[768] Boeing's internal review determined that the absence of a functioning AOA Disagree alert did not adversely impact safety, and because of that, a fix could be deferred until the next software update which was scheduled to occur in 2020 when the 737 MAX 10 variant was expected to enter into service.[769] A Boeing AR concurred with the idea that a fix could be deferred.[770] The decision to defer fixing the inoperable AOA Disagree alert was noted in a Boeing certification summary document in September 2017.[771] A Collins Aerospace-Boeing weekly status meeting, on

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[764] Final KNKT.18.10.35.04 Aircraft Accident Investigation Report, PT. Lion Mentari Airlines, Boeing 737-8 (MAX); PKLQP, Tanjung Karawang, West Java, Republic of Indonesia, 29 October 2018," Komite Nasional Keselamatan Transportasi (KNKT), Republic of Indonesia, issued October 25, 2019, (hereafter referred to as: Lion Air Flight 610 Final Aircraft Accident Investigation Report,"), p. 181, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[765] Letter from then-Acting FAA Administrator Dan Elwell to Chair DeFazio, July 11, 2019. (On file with the Committee).

[766] Boeing Statement on AOA Disagree Alert.

[767] Boeing AOA Disagree Alert Narrative, at TBC T&I 267830 (On file with the Committee). See also Letter from Collins Aerospace's attorney to Chairs DeFazio and Larsen re AOA Disagree Alert, June 20, 2019, p. 8 (On file with the Committee), and 37MAXMDS-S_PR195 (ITRACS PR 195), BATES Number COLLINS_00075 - COLLINS_00076 (On file with the Committee).

[768] Boeing AOA Disagree Alert Narrative at TBC T&I 267830 (On file with the Committee).

[769] Boeing AOA Disagree Alert Narrative at TBC T&I 267830 – 267831 (On file with the Committee).

[770] Boeing AOA Disagree Alert Narrative at TBC T&I 267830 (On file with the Committee).

[771] "737-7/-8/-9 MAX Display System MDS Certification Summary," Document Number D242A408, Release/Revision F, September 8, 2017, BATES Number TBC T&I 267387-267678, at TBC T&1 267617, p. 231, (AOA Disagree Annunciation). (On file with the Committee).

November 7, 2017, also confirmed Boeing's decision to defer fixing the AOA Disagree alert until the 737 MAX 10 entered service.[772]

Boeing considered notifying airlines who were flying the 737 MAX about the defective AOA Disagree alert, and even prepared a Fleet Team Digest on the issue.[773] These digests provide "in-service issues," including economic and safety-related information to Boeing's customers.[774] Ultimately, however, Boeing never sent the digest,[775] and Boeing's customers and MAX pilots remained unaware of the inoperable AOA Disagree alerts until **after** the Lion Air crash.

737-8

Flight Crew
Operations Manual

P. T. Lion Mentari

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Revision Number: 4
Revision Date: August 16, 2018

The Committee's investigation confirmed that Boeing continued to mislead MAX pilots and Boeing customers for more than a year after Boeing learned about the lack of the AOA Disagree alert's functionality in the majority of the 737 MAX fleet. For instance, Boeing provided a Flight Crew Operations Manual (FCOM) on the 737 MAX to P.T. Lion Mentari, the parent company of Lion Air,[776] dated August 16, 2018, a full year after Boeing first learned that the AOA Disagree alert was not working on most 737 MAX aircraft.[777] Yet the FCOM still contained a description of a functioning AOA Disagree alert.[778]

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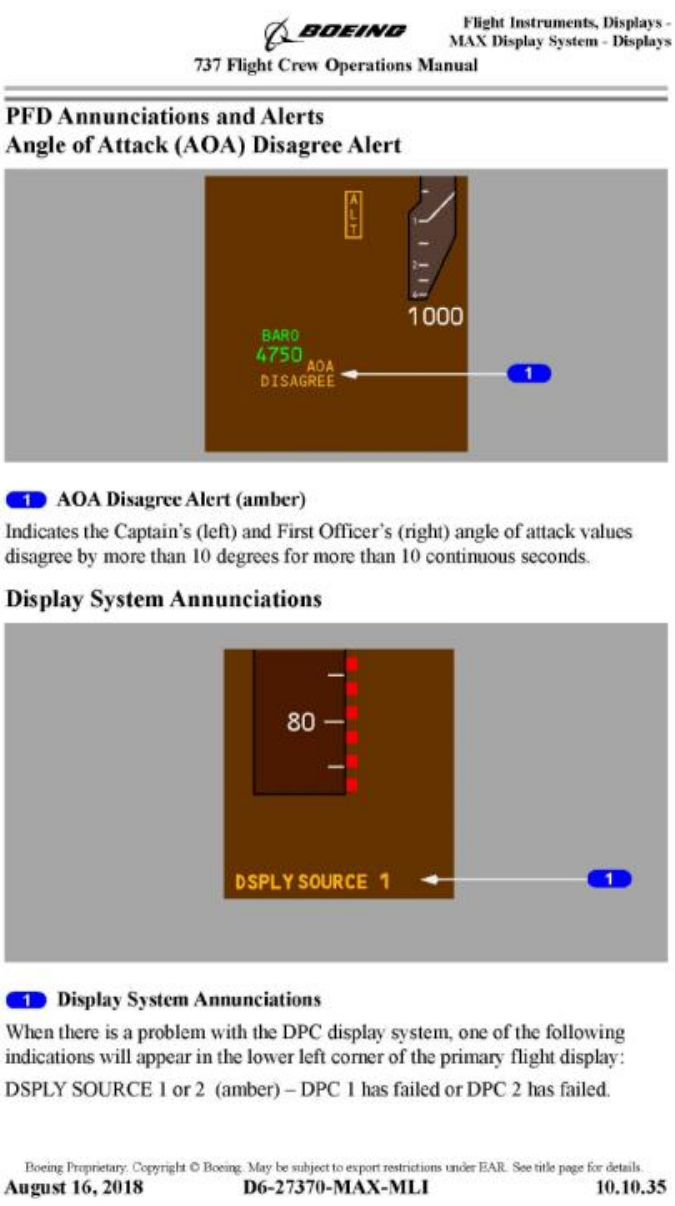
[772] Slide from November 7, 2017 "737 MDS Weekly Telecon" meeting, Collins_00028. (On file with the Committee).
[773] Boeing AOA Disagree Alert Narrative at TBC T&I 267831. (On file with the Committee).
[774] Peter Weertman, "Working Together to Ensure Safe and Efficient Airplane Operations," *AERO* Magazine, Issue 26, Quarter 02, 2007, The Boeing Company, accessed here: https://www.boeing.com/commercial/aeromagazine/articles/qtr_2_07/AERO_Q207_article1.pdf
[775] Boeing AOA Disagree Alert Narrative at TBC-T&I 267831. (On file with the Committee).
[776] "Explanation of Lion Air Company Status and Latest Information on Lion Air JT-610," Press Release, Lion Air, April 9, 2019, accessed here: http://www.lionair.co.id/about-us/newsroom/2019/04/09/explanation-of-lion-air-company-status-and-latest-information-on-lion-air-jt-610
[777] "737-8 Flight Crew Operations Manual – P.T. Lion Mentari," Document Number D6-27370-MAX-MLI-, Revision Number: 4, Revision Date: August 16, 2018," accessed here at p. 175, https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[778] "737-8 Flight Crew Operations Manual – P.T. Lion Mentari," Document Number D6-27370-MAX-MLI-, Revision Number: 4, Revision Date: August 16, 2018," accessed here at p. 177 ("Angle of Attack (AOA) Disagree Alert"), https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Specifically, the FCOM Boeing delivered to Lion Air continued to show pilots an image of a functioning AOA Disagree alert, and assured them that the alert, "Indicates the Captain's (left) and First Officer's (right) angle of attack values disagree by more than 10 degrees for more than 10 continuous seconds."[779]


BOEING
Flight Instruments, Displays - MAX Display System - Displays
737 Flight Crew Operations Manual
PFD Annunciations and Alerts
Angle of Attack (AOA) Disagree Alert
ALT
1000
BARO
4750
AOA
DISAGREE
1
1 AOA Disagree Alert (amber)
Indicates the Captain's (left) and First Officer's (right) angle of attack values disagree by more than 10 degrees for more than 10 continuous seconds.
Display System Annunciations
80
DSPLY SOURCE 1
1
1 Display System Annunciations
When there is a problem with the DPC display system, one of the following indications will appear in the lower left corner of the primary flight display:
DSPLY SOURCE 1 or 2 (amber) – DPC 1 has failed or DPC 2 has failed.
Boeing Proprietary. Copyright © Boeing. May be subject to export restrictions under EAR. See title page for details.
August 16, 2018
D6-27370-MAX-MLI
10.10.35

By the time of the Lion Air crash at the end of October 2018, a majority of the MAX planes that Boeing had delivered to its customers worldwide had flown in revenue service with non-functioning AOA Disagree alerts, unbeknownst to the crews who had flown them. Approximately 250 MAX airplanes had been delivered by November 2018.[780] Given the fact that more than 80 percent of the MAX aircraft at the time did not have an optional AOA Indicator,[781] approximately 200 MAX aircraft were flying at the time with non-functioning AOA Disagree alerts. Neither Lion Air[782] nor Ethiopian Airlines purchased the optional AOA Indicator, so the AOA Disagree alerts on board at the time of both of those crashes were not functioning.[783]

Following the October 29, 2018, Lion Air crash, in which erroneous AOA data appeared to be a contributing factor, Boeing finally briefed the FAA on the defective AOA Disagree alerts on MAX planes lacking optional AOA Indicators.[784] Then, on November 6, 2018, Boeing issued an Operations Manual Bulletin (OMB), which cautioned pilots about the risk of uncommanded downward stabilizer trim due to erroneous AOA data, and noted that one of the indications that a MAX was experiencing erroneous AOA data was the "AOA

[779] Boeing 737-8 Flight Crew Operations Manual, August 16, 2018, TBC-T&I 051408, accessed here at pp. 109-110: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[780] "737 MAX: Deliveries Report," The Boeing Company, accessed here: http://www.boeing.com/commercial/#/orders-deliveries
[781] Boeing AOA Disagree Alert Narrative at TBC-T&I 267828 (On file with the Committee).
[782] Lion Air Flight 610 Final Aircraft Accident Investigation Report at p. 181.
[783] Nick Zazulia, "Boeing Knew the AOA Disagree Alert on the 737 MAX Didn't Work — and Said Nothing," *Aviation Today,* May 6, 2019, accessed here: https://www.aviationtoday.com/2019/05/06/boeing-angle-of-attack-disagree-alert
[784] Boeing Statement on AOA Disagree Alert

DISAGREE alert (if the AOA indicator option is installed)."[785] The following day, the FAA issued an Emergency Airworthiness Directive (AD) which offered a similar warning to MAX pilots.[786]

Also following the Lion Air crash, Boeing decided to accelerate its fix for the defective AOA Disagree alert, instead of waiting until 2020.[787] On November 14, 2018, Boeing provided revised software design requirements to Collins Aerospace and began working with the FAA to certify the revised software.[788] On December 6, 2018, a Boeing Safety Review Board evaluated the AOA Disagree alert issue and concluded that it "was not a safety issue."[789] On February 13, 2019, the FAA informed Boeing that an FAA Corrective Action Review Board (CARB) also found that the lack of an AOA Disagree alert "did not represent an unsafe condition."[790] The FAA certified the AOA Disagree alert software update on February 25, 2019, and Boeing delivered one MAX aircraft with the revised software installed prior to FAA's grounding of the MAX on March 13, 2019.[791]

When questioned at a Committee hearing in October 2019 by Rep. Sharice Davids about Boeing's handling of the its defective AOA Disagree alert, Boeing's then-President and Chief Executive Officer Dennis Muilenburg conceded, "it was part of the airplane baseline. It should have been implemented on the airplanes. It was not correctly implemented. We made a mistake."[792]

John Hamilton
Boeing Chief Engineer
Committee on Transportation and Infrastructure Hearing
October 30, 2019

"I AM NOT SURE WHY WE DIDN'T NOTIFY THE CUSTOMERS OF THAT."

Rep. Davids pressed further, asking, "How do you decide which things are baseline that you are not going to adhere to, and which ones you are?"[793]

Muilenburg responded, "Yes, Congresswoman, we missed on this one. We made a mistake. We made a mistake. And we have owned up to that. We need to fix it."[794]

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[785] Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[786] FAA Emergency Airworthiness Directive # 2018-23-51, November 7, 2018, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf

[787] Boeing AOA Disagree Alert Narrative at TBC-T&I 267833 (On file with the Committee).

[788] Ibid.

[789] Boeing AOA Disagree Alert Narrative at TBC-T&I 267832 (On file with the Committee).

[790] Ibid.

[791] Boeing AOA Disagree Alert Narrative at TBC-T&I 267833 (On file with the Committee).

[792] Testimony of Dennis Muilenburg, Boeing President and Chief Executive Officer, Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 110, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[793] Rep. Sharice Davids, Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 110, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[794] Testimony of Dennis Muilenburg, Boeing President and Chief Executive Officer, Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation &

Rep. Davids asked then-Chief Engineer of Boeing Commercial Airplanes, John Hamilton, about Boeing delivering MAX aircraft to customers with a known, but undisclosed, defect. He responded, "Congresswoman, yes, the airplane did not conform to the spec that—the disagree was not working. I am not sure why we didn't notify the customers of that."[795]

A Missed Opportunity with Lion Air

On October 28, 2018, the day before Lion Air flight 610 crashed into the Java Sea, the aircraft's left AOA sensor was replaced in Denpasar, Indonesia.[796] The replacement AOA sensor was off by 21 degrees, but the mis-calibration went undetected during the installation test.[797]

The mis-calibrated AOA sensor resulted in multiple indications on the flight deck during the aircraft's very next flight from Denpasar to Jakarta, Indonesia. These indications included IAS (indicated airspeed) DISAGREE, ALT (altitude) DISAGREE, and FEEL DIFF PRESS (feel differential pressure) alert lights. Moreover, it activated MCAS and the left control column stick shaker was active throughout the flight.[798]

The Jakarta-bound flight crew struggled to maintain control of the aircraft but were able to do so with help. An off-duty pilot who happened to be dead-heading was seated in the jump seat in the cockpit, and was able to tell the crew to cut power to the motor that was causing the stabilizer to push the plane's nose down.[799] The flight crew was ultimately able to stop the repetitive MCAS activation by using the stabilizer trim cutout switch.[800]

Upon arrival in Jakarta, the Captain of that flight mentioned to an engineer that the aircraft had experienced a problem and filed an entry into the Aircraft Flight Maintenance Log, but did not mention the activation of the stick shaker and did not report "that the STAB TRIM CUTOUT guarded switches were positioned to CUTOUT during flight and after landing returned to the NORMAL position"[801]—that is, that the crew followed the procedure for a runaway stabilizer and turned off, or "cut out," power to the electric motor that moves the horizontal stabilizer (thus neutralizing MCAS), and then the crew reengaged the power after landing.[802]

Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 110, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[795] Testimony of John Hamilton, Chief Engineer of Boeing Commercial Airplanes, Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation & Infrastructure, 116th Congress, First Session, October 30, 2019, pp. 109, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[796] Lion Air Flight 610 Final Aircraft Accident Investigation Report, p. xviii, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[797] Ibid.

[798] Ibid.

[799] John Bacon, "Jump-seat pilot reportedly saved Boeing Max jet one day before Lion Air crash," *USA Today*, March 20, 2019, accessed here: https://www.usatoday.com/story/news/world/2019/03/20/boeing-max-pilot-reportedly-saved-jet-one-day-before-lion-air-crash/3220891002

[800] Lion Air Flight 610 Final Aircraft Accident Investigation Report, p. xviii, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[801] Ibid., p. 168.

[802] Ibid.

Exacerbating the situation, the flight crew was unaware that the AOA Disagree alert was **not** functional on the aircraft,[803] since Lion Air had not purchased an optional AOA Indicator.[804] Had the AOA Disagree alert been functional, it would have indicated the significant difference between the two AOA sensors.[805] It did not. As a result, the crew's ability to detect the faulty AOA sensor was diminished.[806] According to the Indonesian authority's final investigative report:

> …because the AOA DISAGREE message was not available on B737-8 (MAX) aircraft not fitted with the optional AOA indicator, flight crews would not be aware that this message would not appear if the AOA DISAGREE conditions were met. This would contribute to flight crew being denied valid information about abnormal conditions being faced and lead to a significant reduction in situational awareness by the flight crew.[807]

A Missed Opportunity at Xtra Aerospace

The mis-calibrated AOA sensor that was installed in Denpasar was a refurbished part supplied by Xtra Aerospace of Miramar, Florida. The part had been sent to Xtra a year earlier.[808] After it was disassembled, calibrated, and tested, the sensor was approved to return to service in November 2017.[809] However, as noted above, the refurbished AOA sensor, "had a 21° bias," which ultimately went, "undetected during the installation test in Denpasar."[810]

On October 25, 2019, the FAA revoked Xtra Aerospace's Repair Station Certificate for failing "to comply with requirements to repair only aircraft parts on its list of parts acceptable to the FAA that it was capable of repairing," and failing, "to comply with procedures in its repair station manual for implementing a capability list in accordance with the Federal Aviation Regulations."[811] According to the FAA, "The company also did not substantiate that it had adequate facilities, tools, test equipment, technical publications, and trained and qualified employees to repair parts on its capability list."[812]

At Least Three Missed Opportunities to Catch Faulty AOA Sensor

In short, there were at least three opportunities to catch the faulty AOA sensor before Lion Air flight 610 departed. First, testing at Xtra Aerospace could have discovered the AOA sensor's mis-calibration before the refurbished part was cleared for return to service. Second, the mis-

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[803] Ibid., p. 181.
[804] Ibid., p. 46.
[805] Ibid., p. 178.
[806] Ibid.
[807] Ibid., p. 181.
[808] Dominic Gates, "FAA shuts down Florida repair firm that supplied faulty Lion Air sensor on Boeing 737 MAX," *Seattle Times*, October 25, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-shuts-down-revokes-certificate-of-florida-repair-firm-that-supplied-faulty-lion-air-sensor
[809] Ibid.
[810] Lion Air Flight 610 Final Aircraft Accident Investigation Report, p. xviii, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf
[811] FAA Press Release – FAA Revokes Repair Station Certificate of Xtra Aerospace of South Florida, October 25, 2019, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24314
[812] Ibid.

calibration could have been caught when the part was installed on the aircraft in Denpasar. Third, and most importantly, a properly functioning AOA Disagree alert could have alerted the Jakarta-bound flight crew, and ultimately aircraft maintenance, that there was a potential problem with an AOA sensor.

Culture of Omission

Boeing, the FAA, and other aviation experts do not believe the AOA Disagree alert is a safety critical component. However, the tale of how Boeing dealt with the AOA Disagree alert issue is extremely important and deeply disturbing. While Boeing has said its senior leadership was unaware of the AOA Disagree alert issue at the time, it is clear multiple Boeing employees at multiple levels in the company were fully aware the AOA Disagree alerts were not functioning on the majority of the 737 MAX fleet. Some even initiated the process of informing Boeing's customers of this fact. For whatever reason that information never made its way out the door at Boeing and to Boeing's customers. Worse, Boeing continued to knowingly manufacture and deliver dozens of MAX aircraft with a defective component to its customers, violating their approved type design.

Boeing made a decision to simply omit the fact that the AOA Disagree alert on the majority of its 737 MAX fleet were inoperative not only from airlines, but from MAX pilots and the FAA as well. This paints a troubling picture of the corporate and cultural challenges Boeing must squarely face to regain the trust of Federal regulators, its customers, and the flying public. Boeing's actions may not have directly jeopardized the safety of any aircraft, but the way Boeing handled this issue endangered the reputation of the company.

For its part, the FAA has failed to hold Boeing accountable for its actions on this issue. This is despite the fact the then-Acting FAA Administrator made it clear to the Committee that once Boeing decided to include the AOA Disagree alert as a standard feature on its MAX aircraft, it "was required to be installed and functional on all 737 MAX airplanes Boeing produced," per its approved type design.[813] The AOA Disagree alert issue also highlights the fact that the FAA simply does not have enough insight into Boeing's activities in order to provide the robust oversight that is necessary and expected of this Federal regulatory agency.

[813] Letter from then-Acting FAA Administrator Dan Elwell to Chair DeFazio, July 11, 2019 (On file with the Committee).

7. Boeing 737 MAX Pilot Training

-Boeing 737 MAX Pilot Training-

INVESTIGATIVE FINDINGS

- Guaranteeing that the 737 MAX did not require simulator training for pilots transitioning from the 737 NG to the 737 MAX was a key Boeing objective of the 737 MAX program.[814]
- This goal demanded that pilot differences training be kept to 16 hours or less of Level B (non-simulator) training requirements.[815] In the end, the FAA estimated that its approved computer-based training for the MAX could be completed in approximately two hours.[816]
- Ensuring no pilot simulator training was required was also a key feature of Boeing's business strategy for marketing the MAX to airlines.[817]
- Boeing's Chief Project Engineer on the 737 MAX program acknowledged in an interview with Committee staff that ensuring no simulator training was required was a "design objective" of the MAX program.[818]
- Boeing had tremendous financial incentives to ensure the MAX program met this goal.[819]
- In December 2011, Boeing agreed to pay Southwest Airlines $1 million per MAX airplane that Boeing delivered to Southwest if its pilots were unable to operate the 737 NG and 737 MAX interchangeably due to any reason.[820] In addition, if the FAA required more than 10 hours of pilot training and/or required flight simulator training, Boeing would reimburse SWA for any direct training expense that exceeded 10 hours.[821]
- In July 2014, more than two years before the FAA determined its approved pilot training for the MAX, Boeing publicly claimed no simulator training would be required on the MAX.[822]

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[814] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.
[815] Boeing internal email from former 737MAX Chief Project Engineer to Boeing Commercial Airplanes (BCA) Senior Chiefs and Functional Leaders, "Subject: 737MAX Firm Configuration Status/Help Needed," Sent: May 4, 2013, 11:35:58 AM, BATES Number TBC-T&I049683-049684. (On file with the Committee).
[816] "FAA Responses to Follow-Up Questions from House T&I Staff," Sent: September 6, 2019, BATES Number FAA-T&I-000031938 – 000031939. (On file with the Committee).
[817] Boeing slide presentation to Ethiopian Airlines, "Subject: 737MAX, 777X & 787-9 Executive Review," March 4, 2014, BATES Number TBC-T&I00199-002000, 002018, at TBC-T&I002018, accessed at p. 126 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[818] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.
[819] David Shepardson and Tracy Rucinski, "U.S. lawmakers question Boeing's $1 mln rebate clause for Southwest 737 MAX orders," *Reuters*, October 30, 2019, accessed here: https://www.reuters.com/article/us-boeing-airplane-southwest/u-s-lawmakers-question-boeings-1-mln-rebate-clause-for-southwest-737-max-orders-idUSKBN1X92D4
[820] Letter from Southwest Airlines to Chair, Committee on Transportation and Infrastructure, and Chair, Subcommittee on Aviation, U.S. House of Representatives, July 26, 2019. (On file with the Committee).
[821] Ibid.
[822] "Boeing Selects Supplier for 737 MAX Full-Flight Simulator," Press Release, The Boeing Company, July 11, 2014, accessed here: https://boeing.mediaroom.com/2014-07-11-Boeing-Selects-Supplier-for-737-MAX-Full-Flight-Simulator

INVESTIGATIVE FINDINGS - Continued

- In February 2015, Boeing's 737 Chief Technical Pilot wrote that MAX simulator training would be "unrecoverable" for some Boeing customers due to the lack of simulators.[823]

- The management directive to have no simulator training constricted technical design decisions on the 737 MAX—limiting some safety features, such as the inclusion of a synthetic airspeed indicator, that may have jeopardized the no simulator training goal.[824]

- In 2015, the FAA believed several technical systems on the MAX, excluding MCAS, would require simulator training for MAX pilots.[825] In the end, the FAA did not require any simulator training for pilots transitioning from the 737 NG to the 737 MAX.

- In September 2016, the Committee has learned, Boeing granted its team of technical pilots the company's Commercial Aviation Services (CAS) Service Excellence Award for their role in "developing the MAX Level B [non-simulator] differences training...."[826]

- The influence of Boeing management's directive to have no simulator training for the MAX percolated through the entire 737 MAX program. As a result of this directive, the 737 Chief Technical Pilot successfully talked one Boeing customer airline out of establishing simulator training requirements for its MAX pilots shortly after the MAX was certified by the FAA.[827]

- The 737 Chief Technical Pilot used incredibly disparaging language to describe inquiries from Boeing customer airlines that asked about pilot simulator training on the 737 MAX and said Boeing "will not allow" foreign regulators to require simulator training.[828]

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[823] Boeing internal email from former 737 Chief Technical Pilot to former 737MAX VP/GM, former 737MAX Chief Project Engineer, and others, "Subject: HELP NEEDED Request: 737 CL Program decision, RCAS/MAX training," Sent: Friday, February 27, 2015, 3:29 PM, BATES Number TBC-T&I552663-552666 at TBC-T&I 552664 – 552665. (On file with the Committee).

[824] Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, accessed at p. 1 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[825] FAA Memorandum, From: Seattle Aircraft Evaluation Group (SEA-AEG), To: Flight Standards, "Subject: Boeing 737 MAX Type Rating Determination and Pilot Training Requirements," May 10, 2015, BATES Number, FAA-DEFAZIO-000032887-32890, accessed at p.231 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[826] Boeing internal email, "Subject: RE: Weekly inputs," September 21, 2016, 4:26:33 PM, BATES Number TBC-T&I 552192. (On file with the Committee).

[827] See: Boeing internal email, "Subject: RE: 737 MAX ATB/RTL FOTB" Sent: Monday, June 5, 2017, 8:01 PM (p. 14); Boeing email to airline customer, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Tuesday, June 6, 2017 11:01:40 AM (p. 34); Airline customer email to Boeing, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 12:12 AM (p. 32); and Boeing internal email, "Subject: FW: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Wednesday, June 7, 2017, 10:01:41 AM (p. 32); accessed here (at page numbers indicated in parenthesis): https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[828] Boeing internal email, "Subject: RE: Flight Transition costs," Sent: March 28, 2017, 9:00:58 AM, accessed at p. 28 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

INVESTIGATIVE FINDINGS - Continued

- The 737 Chief Technical Pilot also boasted that his efforts to talk airlines out of simulator training saved Boeing "a sick amount of $$$$."[829]

- In January 2020, Boeing made a stunning reversal of its previous goal to prevent pilot simulator training and recommended that simulator training be required for all MAX pilots once the plane is ungrounded and returns to service.[830]

Faulty Assumptions

Development of the MAX was marred by multiple faulty assumptions and financial pressures from the very start. The assumption that pilots transitioning from the 737 NG to the 737 MAX would only need a limited amount of differences training and **no** simulator training diminished safety, minimized the value of pilot training, and inhibited technical design improvements. The increased costs to Boeing's customer airlines in providing simulator training for MAX pilots and the increased costs to Boeing of adding new design features that could lead to heightened pilot training requirements drove critical decisions on the 737 MAX program.

Boeing has tacitly conceded the failure of its previous pilot training assumptions by announcing in January 2020 that it will now recommend simulator training for MAX pilots.[831] On the technical side, Boeing's faulty assumptions undermined safety and led, for example, to a lack of redundant features on MCAS.[832] Financial considerations also contributed to Boeing's decisions not to include certain safety features on the aircraft, such as a synthetic airspeed indicator, that would have increased costs and may have created potential simulator training requirements.[833]

Financial pressures to limit pilot training requirements permeated critical design and development decisions within the MAX program. Boeing assumed that despite new technologies being added to the MAX aircraft, particularly the inclusion of MCAS, pilots would not need to be specifically trained to respond to potential MCAS failures, for instance, or even to be aware MCAS existed.[834] More than any other program objective, ensuring that the FAA's pilot training requirements for the MAX did **not** include simulator training had an incredibly significant cascading effect on the 737 MAX program that undermined the safety of the flying public.

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[829] Boeing internal instant message, December 12, 2017, BATES Number TBC-T&I549015 – TBC-T&I549016. (On file with the Committee).
[830] "Boeing Statement on 737 MAX Simulator Training," Press Release, The Boeing Company, January 7, 2020, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130596
[831] Ibid.
[832] Boeing employee email, "RE: MCAS Stab Rapid Reversal on PSIM Model," Sent: December 17, 2015,10:44:54 AM, BATES Number TBC-T&I 010584 - TBC-T&I 010586 at TBC-T&I 010584, accessed at p. 121 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[833] Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1 accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[834] Email from 737 Chief Technical Pilot to FAA, "Subject: MCAS lives in both FCCs," Sent: Wednesday, March 30, 2016, 11:16:45.

Most alarmingly, Boeing made these assumptions despite the fact that it had internal test data that contradicted them.[835] In 2012, for instance, it took one of Boeing's own test pilots more than 10 seconds during a simulator test to respond to MCAS activation.[836] The pilot, "found this catastrophic[.]"[837] Boeing did not inform the FAA about this test data and appears to have discounted the test results, falsely assuming that pilots would quickly recognize and respond to uncommanded[838] MCAS activation.[839] In the end, MCAS played a key role in both MAX crashes.

In the wake of the Lion Air and Ethiopian Airlines crashes, despite Boeing's own simulator test results, both Boeing and the FAA tended to place the blame for the accidents on foreign-trained pilots and discounted technical design flaws on the MAX.[840] In a briefing to Chair DeFazio and Subcommittee on Aviation Chair Larsen in February 2019 concerning the Lion Air crash, Ali Bahrami, the FAA's Associate Administrator for Aviation Safety, described the crash as a "one off" event and attributed it to poor pilot performance.[841]

However, Boeing's own test data, cited above, showed that a Boeing test pilot struggled to effectively respond to uncommanded MCAS activation in a MAX simulator and found the condition "catastrophic[.]"[842] Real life was no different. Pilots on the doomed Lion Air and Ethiopian Airlines

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[835] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, and
Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at pp. 164 and 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[836] Internal Boeing email, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 1:41 PM, BATES Number TBC-T&I 131226 – 131227. (On file with the Committee).

[837] Ibid.

[838] MCAS was designed to activate automatically without any pilot command. Use of the term "uncommanded" in connection with MCAS activation here is for consistency with Boeing's own Functional Hazard Assessments which measured, "Uncommanded MCAS function operation to pilot reaction[,]" and determined that a pilot reaction time of greater than 10 seconds could be "catastrophic[.]" See: Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, pp. 163, 173, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[839] Internal Boeing email, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 1:41 PM, BATES Number TBC-T&I 131226 – 131227. (On file with the Committee).

[840] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 173 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[841] See: Peter Economy, "Boeing CEO Puts Partial Blame on Pilots of Crashed 737 MAX Aircraft for Not 'Completely' Following Procedures," *Inc.*, April 30, 2019, accessed here: https://www.inc.com/peter-economy/boeing-ceo-puts-partial-blame-on-pilots-of-crashed-737-max-aircraft-for-not-completely-following-procedures.html; Curt Devine, Aaron Cooper, and Drew Griffin, "Pilots union to Boeing: 'Inexcusable' to blame pilots for 737 Max crashes," *CNN Business*, May 23, 2019, accessed here: https://www.cnn.com/2019/05/23/business/american-airlines-boeing-pilots-union/index.html; and Testimony of Daniel K. Elwell, Acting Administrator, Federal Aviation Administration, Hearing titled, "Status of the Boeing 737 MAX," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, pp. 32-33, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

[842] Briefing to House Committee on Transportation and Infrastructure Chair Peter DeFazio and Subcommittee on Aviation Chair Rick Larsen by Ali Bahrami, Associate Administrator for Aviation Safety, Federal Aviation Administration (FAA), February 14, 2019.

[843] Internal Boeing email, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 1:41 PM, BATES Number TBC-T&I 131226 – 131227. (On file with the Committee).

flights struggled to regain control of the MAX aircraft following the erroneous activation of MCAS that led to those two crashes.[843]

In a hearing before the Subcommittee on Aviation in May 2019, Robert Sumwalt, Chair of the National Transportation Safety Board (NTSB), discussed the importance of pilot training requirements and the assumptions made by aircraft manufacturers.[844] "I think it is important to point out that if an aircraft manufacturer is going to sell airplanes all across the globe, then it is important that pilots who are operating those airplanes in those parts of the globe know how to operate them," he said. "And I think that is important."[845] Mr. Sumwalt also concluded that while U.S. piloting standards are very good, "I don't think that is part of the answer. … [T]he airplane has to be trained to the lowest common denominator."[846]

In fact, the FAA has issued Advisory Circulars pointing out that "when assessing the ability of the flightcrew to cope with a failure condition," manufacturers should consider whether the flightcrew can respond to these failures **"without requiring exceptional pilot skill or strength…."**[847] *(Emphasis added.)* While both Boeing and the FAA have pointed to pilot performance as a factor in the MAX crashes[848] and while pilot performance is often a contributing factor in any aircraft accident, neither Boeing nor the FAA can shirk their responsibility for developing and certifying an aircraft that was not safe to fly for all pilots.

What makes Boeing's decision to stick to its goal of no simulator training most troubling is the fact that Boeing had information from its own test data suggesting that some pilots, even U.S.-trained Boeing test pilots, would need more training on the MAX, particularly to respond to an erroneous activation of MCAS effectively. However, Boeing appears to have discounted this test data and ignored this evidence, assuming that **all** pilots would respond quickly and effectively to uncommanded MCAS activation. Those assumptions were drastically wrong.

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[843] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. xviii and 19-28, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and "Ethiopian Airlines Flight 302 Interim Investigation Report," pp. 130-132, accessed here: http://www.aib.gov.et/wp-content/uploads/2020/documents/accident/ET-302%20%20Interim%20Investigation%20%20Report%20March%209%202020.pdf

[844] Testimony of Robert L. Sumwalt III, Chairman, National Transportation Safety Board, Hearing titled, "Status of the Boeing 737 MAX," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, pp. 67-68, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf

[845] Ibid.

[846] Ibid.

[847] "Subject: System Design and Analysis," Advisory Circular, AC No: 25.1309-1A, Federal Aviation Administration, Department of Transportation, June 21, 1988, p. 15, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1309-1A.pdf

[848] See: Testimony of Daniel K. Elwell, Acting Administrator, Federal Aviation Administration, Hearing titled, "Status of the Boeing 737 MAX," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, May 15, 2019, pp. 32-33, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37277/pdf/CHRG-116hhrg37277.pdf; Michael Laris, Lori Aratani, and Ashley Halsey III, "FAA Chief says pilot decisions contributed to Boeing 737 Max crashes," *Washington Post*, May 15, 2019, accessed here: https://www.washingtonpost.com/transportation/2019/05/15/faa-chief-be-pressed-boeing-max-while-would-be-replacement-faces-questions-his-approach-air-safety and Dominic Gates, "Ethiopian Airlines calls criticism of its pilots an effort to 'divert public attention' from Boeing 737 MAX flaws," *Seattle Times*, May 17, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/ethiopian-airlines-calls-criticism-of-its-pilots-an-effort-to-divert-public-attention-from-boeing-737-max-flaws

As Captain ("Sully") Sullenberger said in testimony to the Subcommittee on Aviation in June 2019:

> It is clear that the original version of MCAS was fatally flawed and should never have been approved. It has been suggested that even if the MCAS software had flaws, the pilots on these flights should have performed better and been able to solve the sudden unanticipated crises they faced. Boeing has even said that in designing MCAS they did not categorize a failure of MCAS as critical because they assumed that pilot action would be the ultimate safeguard.[849]

Captain Sullenberger added, "We should all want pilots to experience these challenging situations for the first time in a simulator, not in flight with passengers and crew on board."[850] Boeing's Level B training goals for the MAX program, however, prevented that from happening.

Design Objective: 737 MAX Level B Training

In a lengthy interview with Committee staff, Michael Teal, the former Chief Project Engineer for the 737 MAX program and a Boeing Vice President, said efforts to obtain Level B (non-simulator) pilot training requirements or less from the FAA "was a design objective."[851] However, he said, "In the end, of course, the FAA was the one that would determine whether it's Level B." Mr. Teal said that Boeing "expected Level B" if it followed its "design process" and "criteria." [852]

He also said that the FAA "couldn't indicate to me whether or not [the MAX] was at Level B, C, or what the determination was until they completed their evaluation. And their evaluation would include flying the airplane through a series of what we call T1, T2, T3 tests. And we had to complete that process before they could make their ruling."[853] The FAA did not make its provisional determination to require Level B training until August 2016.[854]

However, the supposition that Boeing was simply going through the process and waiting for the FAA to make its determination on pilot training requirements is not supported by the facts of the Committee's investigation. Level B training was not just a "design objective," rather it was imperative to the financial success of the MAX program. Pilot training requirements affected multiple parts of the MAX program, and Boeing was aggressive about making certain the FAA did not require simulator training (e.g., greater than Level B training) for pilots transitioning from the 737 NG to the 737 MAX.

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[849] Prepared Statement of Captain Chesley B. "Sully" Sullenberger III, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/Sully%20Sullenberger%20Testimony.pdf

[850] Ibid.

[851] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020, accessed here: https://transportation.house.gov/committee-activity/boeing-737-max-investigation

[852] Ibid.

[853] Ibid.

[854] FAA letter to The Boeing Company, "Subject: Boeing 737 MAX Pilot Qualification Plan (PQP) Gate 4," August 17, 2016, BATES Number TBC-T&I 010895. (On file with the Committee).

7. Boeing 737 MAX Pilot Training

In September 2013, Mark Forkner, Boeing's 737 Chief Technical Pilot, prepared a presentation that listed "Flight Crew Difference training level no greater than level B from 737NG family" as one of the "Ground Rules" for the 737 MAX.[855] In March 2014, a senior Boeing employee expressed concern that adding new "Asymmetry and Authority alerts" to the 737 MAX could potentially endanger Level B computer-based training requirements. "We told all our customers MAX will only require up to Level B training," wrote the Boeing employee.[856] The employee was clearly concerned about the impact increased training requirements could have. "This would have very severe consequences for the MAX program," the employee wrote to Boeing colleagues more than two years before the FAA made a decision regarding pilot training requirements.[857] Furthermore, in a May 2014 email to a Boeing colleague discussing an upcoming briefing to the FAA regarding pilot training issues, Mr. Forkner, wrote: "We definitely want to emphasize how similar the MAX will be to the NG with regards to handling characteristics/qualities, as opposed to different/changed."[858]

Mark Forkner
former 737 Chief Technical Pilot
(On briefing FAA on the MAX)
May 7, 2014

"WE DEFINITELY WANT TO EMPHASIZE HOW SIMILAR THE MAX WILL BE TO THE NG WITH REGARDS TO HANDLING CHARACTERISTICS/QUALITIES, AS OPPOSED TO DIFFERENT/CHANGED."

Boeing was not simply pushing hard to obtain Level B pilot training, it was blurring the lines between what it "hoped" the FAA would determine and the FAA's actual decision concerning pilot training requirements. In 2014 marketing materials to a potential customer airline, for instance, Boeing had slides that said pilot training would be "limited to Level B Training only" and only included a small note indicating that this was "pending 737 MAX certification."[859]

In addition, despite Mr. Teal's assertion in the transcribed interview that Boeing was waiting for the FAA to make a determination on the MAX pilot training requirements, in July 2014, more than two years before the FAA would complete its pilot training evaluations and flight testing to make a determination, Boeing boldly claimed in a press release that no simulator training would be required.[860] As an indication of how unusual Boeing's statement was, a Rockwell Collins official emailed FAA in April 2015 to inquire if Boeing had some level of agreement from the FAA that

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[855] Presentation by 737 Chief Technical Pilot, "737 MAX: Flight Crew Operations," September 2013, Boeing, BATES Number TBC-T&I 552228, 552230, and 552233. (On file with the Committee).
[856] Boeing internal email, "Subject: RE: Update: ROLL/YAW ASYMMETRY NNCs," March 14, 2014 11:41 AM, BATES Number TBC-T&I 552823-552824. (On file with the Committee).
[857] Ibid.
[858] Email from former 737 Chief Technical Pilot to Boeing employee, "Subject: RE: Systems Summary briefing," Sent: Wednesday, May 7, 2014, 8:22 AM, BATES Number TBC-T&I180771. (On file with the Committee).
[859] Boeing slide presentation to Ethiopian Airlines, "Subject: 737MAX, 777X & 787-9 Executive Review," March 4, 2014, BATES Number TBC-T&I001999-002000, 002018, at TBC-T&I002018, accessed at p. 126 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[860] "Boeing Selects Supplier for 737 MAX Full-Flight Simulator," Boeing News Release, July 11, 2014, accessed here: https://boeing.mediaroom.com/2014-07-11-Boeing-Selects-Supplier-for-737-MAX-Full-Flight-Simulator

would allow it to make this claim.[861] The FAA had not, in fact, made any agreements with Boeing and, as noted above, would not establish its final position on MAX pilot training requirements for two more years.

Despite that reality, the Boeing press release said there would only be a "short differences training course for" pilots transitioning from the 737 NG to the 737 MAX.[862] "Pilots already certified on the Next-Generation 737 will not require a simulator course to transition to the 737 MAX," the press release claimed.[863] There was no caveat in the press release informing the public that the FAA had not yet made that decision.

Boeing Press Release
July 11, 2014

"PILOTS ALREADY CERTIFIED ON THE NEXT-GENERATION 737 WILL NOT REQUIRE A SIMULATOR COURSE TO TRANSITION TO THE 737 MAX."

Marketing the MAX

The "design objective" to obtain Level B training requirements or less from the FAA played a critical role in marketing the MAX to Boeing's customers. A central component of Boeing's marketing strategy for the 737 MAX was that pilots who were certified to operate the 737 NG would require minimal, non-simulator-based training to obtain certification on the 737 MAX.[864] Because airlines stood to incur increased training costs if 737 NG-certified pilots were required to complete simulator-based instruction to earn certification on the 737 MAX, Boeing marketed the MAX with the premise and the promise that pilots—following minimal "differences training"—could operate the 737 NG and MAX interchangeably.[865]

In addition to the costs that airlines would incur if they were required to provide simulator-based training to their pilots, the task of running thousands of pilots through the few simulators that exist could take many months and slow airlines' ability to get their airplanes into service.[866] According to the aviation industry trade publication, *Flight Global*, as of January 2020, only 34 full-motion 737 MAX simulators existed worldwide, and U.S. airlines only had a "handful."[867] Southwest Airlines, based in Dallas, had three MAX simulators in January 2020 and reportedly was expected to receive three additional MAX simulators during the year.[868] As of January 2020, Southwest had nearly 10,000 pilots,[869] and when the MAX was grounded, the airline had 34 MAX aircraft in its fleet

[861] Rockwell Collins email to FAA, "Subject: 737 MAX training question," Sent: Wednesday, April 29, 2015, 7:12 AM, BATES Number FAA-DEFAZIO-000032886, accessed at p. 230 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[862] "Boeing Selects Supplier for 737 MAX Full-Flight Simulator," The Boeing Company, July 11, 2014, accessed here: https://boeing.mediaroom.com/2014-07-11-Boeing-Selects-Supplier-for-737-MAX-Full-Flight-Simulator
[863] Ibid.
[864] Ibid.
[865] Ibid.
[866] Jon Hemmerdinger, "Boeing changes mind, recommends simulator training for all 737 Max pilots," *Flight Global,* January 7, 2020, accessed here: https://www.flightglobal.com/air-transport/boeing-changes-mind-recommends-simulator-training-for-all-737-max-pilots/136028.article
[867] Ibid.
[868] Kyle Arnold, "Boeing says 737 Max pilots should get simulator training, including thousands at American and Southwest," *Dallas Morning News*, January 7, 2020, accessed here: https://www.dallasnews.com/business/airlines/2020/01/07/boeing-says-737-max-pilots-should-get-simulator-training-including-thousands-at-american-and-southwest
[869] "SWAPA Fast Facts," Southwest Airlines Pilots Association, January 1, 2020, accessed here: https://swaparesources.s3-us-west-2.amazonaws.com/assets/public_article/FastFacts2020.pdf

with plans to increase its MAX fleet up to nearly 400 aircraft by 2026.[870] American Airlines, based in Fort Worth, had 24 MAX airplanes as of the end of 2019—with 76 future MAX airplane deliveries planned—and just one MAX simulator for its 4,200 737 pilots.[871] It could take years to move all of these pilots through these MAX simulators. For airlines such as Southwest and American that operate variants of the 737, this training bottleneck would limit the availability of pilots who are certified to fly the 737 MAX and affect the efficiency of their "mixed fleet" operations.[872]

In February 2015, well before the FAA evaluated what training requirements would be necessary on the MAX, Mr. Forkner addressed this very issue. In an email to Keith Leverkuhn, former General Manager of the 737 MAX program, and Mr. Teal, Mr. Forkner wrote, "HELP NEEDED: Request Program Leadership intervention with the FAA Aircraft Evaluation Group (AEG)." [873] Mr. Forkner's email explained that AEG personnel were maintaining that they would not be able to make any preliminary training level determinations until after completion of T-3 Test evaluations which were not expected to happen until late 2016.[874] "This carries tremendous risk to the Program," wrote Mr. Forkner, "as differences greater than Level B will be unrecoverable for our early NG/MAX customers like [redacted], due to simulator availability."[875]

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[870] "Southwest Airlines Reports 47th Consecutive Year of Profitability," Southwest Airlines Company, January 23, 2020, p. 3 (showing fleet and capacity) and p. 10 (showing 737 Delivery Schedule as of December 31, 2019) accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={DBC2A948-97F6-47E0-B3A2-5E844D962A08} and Kyle Arnold, "Boeing says 737 Max pilots should get simulator training, including thousands at American and Southwest," *Dallas Morning News*, January 7, 2020, accessed here: https://www.dallasnews.com/business/airlines/2020/01/07/boeing-says-737-max-pilots-should-get-simulator-training-including-thousands-at-american-and-southwest

[871] "Fleet Fact Sheet," American Airlines, updated February 2020, accessed here: https://s21.q4cdn.com/616071541/files/doc_downloads/FactSheets/2020/Fleet-Facts_022020.pdf and Kyle Arnold, "Boeing says 737 Max pilots should get simulator training, including thousands at American and Southwest," *Dallas Morning News*, January 7, 2020, accessed here: https://www.dallasnews.com/business/airlines/2020/01/07/boeing-says-737-max-pilots-should-get-simulator-training-including-thousands-at-american-and-southwest

[872] In mixed fleet operations, a pilot could be scheduled, for example, to fly a 737 NG on an earlier flight and a 737 MAX on a later flight during the pilot's duty day.

[873] Boeing internal email from former 737 Chief Technical Pilot to former 737MAX VP/GM, former 737MAX Chief Project Engineer, and others, "Subject: HELP NEEDED Request: 737 CL Program decision, RCAS/MAX training," Sent: Friday, February 27, 2015, 3:29 PM, BATES Number TBC-T&I552663-552666 at TBC-T&I 552664 – 552665. (On file with the Committee).

[874] Ibid. Note that the System Differences Test and Validation of Training and Checking—Test 3 (T3) "is used to evaluate the proposed differences and/or related aircraft differences training, checking, and training devices at level B, C, or D;" see: "Subject: Guidance for Conducting and Use of Flight Standardization Board Evaluations," Advisory Circular, AC No: 120-53B, Change 1, Federal Aviation Administration, Department of Transportation, October 24, 2016, Appendix 3, p. 5, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-53B_Chg_1.pdf

[875] Boeing internal email from former 737 Chief Technical Pilot to former 737MAX VP/GM, former 737MAX Chief Project Engineer, and others, "Subject: HELP NEEDED Request: 737 CL Program decision, RCAS/MAX training," Sent: Friday, February 27, 2015, 3:29 PM, BATES Number TBC-T&I552663-552666 at TBC-T&I 552664 – 552665. (On file with the Committee).

Gambling on Level B

Although Boeing assumed that the FAA would approve Level B (non-simulator) training for the MAX, that was a tremendous and risky gamble given the multiple new features on the MAX and the company's business strategy to sell the MAX to customers as **not** requiring simulator training years before the FAA had made a determination on this issue. In December 2011, Boeing entered into a contract with Southwest Airlines, its U.S. launch customer, that laid out financial terms and conditions if Boeing failed to obtain a Level B pilot training requirement from the FAA.[876] Southwest's first 737 MAX began scheduled service on October 1, 2017.[877]

As part of the contract, Boeing agreed to pay Southwest $1 million per MAX airplane that Boeing delivered to Southwest if its pilots were unable to operate the 737 NG and 737 MAX "interchangeably" "due to any reason."[878] On top of that, Boeing agreed to reimburse Southwest for any training expenses that exceeded 10 hours if the FAA required more than 10 hours of pilot training and/or required flight simulator training.[879] That agreement left Boeing with significant financial exposure if it failed to obtain Level B (non-simulator) training requirements from the FAA.

When Ethiopian Airlines flight 302 crashed in March 2019, Southwest had 34 MAX aircraft in its fleet.[880] In October 2019, one year after the Lion Air flight 610 crash, Southwest had 246 firm MAX orders, 34 of its MAX aircraft were grounded, and it had the option to purchase 115 additional MAX aircraft.[881] Thus, if the FAA had required pilot simulator training for MAX pilots, Boeing would have been required to pay Southwest nearly $400 million to offset the simulator-based pilot training requirements.

Although obtaining Level B or less training requirements was a central pillar of the 737 MAX program, the program's two most senior officials, Mr. Leverkuhn, the former General Manager of the 737 MAX program and Mr. Teal, the program's former Chief Project Engineer, said in separate interviews with Committee staff that they were not involved in the Southwest Airlines contract negotiations and were largely unaware of the contract.[882] They also said they did not believe that Mr. Forkner was involved in those negotiations either.[883] Mr. Forkner left Boeing in July 2018

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[876] Letter from Southwest Airlines to Chair, Committee on Transportation and Infrastructure, and Chair, Subcommittee on Aviation, U.S. House of Representatives, July 26, 2019. (On file with the Committee).
[877] "Southwest Corporate Fact Sheet," Fleet as of December 31, 2019, Southwest Airlines, accessed here: https://www.swamedia.com/pages/corporate-fact-sheet#fleet
[878] Letter from Southwest Airlines to Chair, Committee on Transportation and Infrastructure, and Chair, Subcommittee on Aviation, U.S. House of Representatives, July 26, 2019. (On file with the Committee).
[879] Ibid.
[880] "Southwest Airlines Statement Regarding 737 MAX 8," Southwest Airlines Company, March 13, 2019, accessed here: http://www.southwestairlinesinvestorrelations.com/tools/viewpdf.aspx?page={DEA8FE8F-94F9-4DBE-BC91-F63964B49593}
[881] See: "Southwest Corporate Fact Sheet," Southwest Airlines Company, 2020, accessed here: https://www.swamedia.com/pages/corporate-fact-sheet#fleet; and "Southwest Reports Record Third Quarter Net Income And Earnings Per Share," Southwest Airlines Company, October 24, 2019, accessed here: http://www.southwestairlinesinvestorrelations.com/news-and-events/news-releases/2019/10-24-2019-112936719
[882] Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020, and Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.
[883] Ibid.

after nearly seven years and took a position as First Officer at Southwest Airlines.[884] According to recent news reports, Mr. Forkner took an early buyout at Southwest and planned to leave his position there at the end of August 2020.[885]

Both Mr. Leverkuhn and Mr. Teal said that the Level B training issue was not something that was specifically briefed to higher management at Boeing, including the CEO of The Boeing Company or the CEO of the Boeing Commercial Airplanes (BCA) division.[886] Mr. Leverkuhn acknowledged that had Boeing not obtained Level B training, one impact would have been in obtaining enough MAX simulators for customer airlines' flightcrews, which would have delayed getting the MAX into service.[887] He also said the "larger impact" would have been compensating the airlines "in some manner."[888]

Mr. Teal, however, was always confident Boeing would meet its Level B training goal. "[G]reater than Level B training was never really a concern," he said.[889] He was apparently so confident in meeting this program goal that he says he does not recall talking about it with senior Boeing management. "I don't recall ever talking about it, because we were very confident that we would meet Level B."[890]

Level B Implications to MCAS and other MAX Systems

In his interview with Committee staff, Mr. Teal also claimed that he did not believe MCAS was a concern in regard to the impact it could have on obtaining Level B training. "I don't recall the MCAS ever being a concern associated with level B training," he said.[891] That statement, however, does not square with the facts. In May 2013, Mr. Teal sent an email to senior leaders on the MAX team regarding significant risk issues. That email very specifically tied the inclusion of MCAS in the aircraft to potentially jeopardizing Boeing's goal of obtaining Level B training. Specifically, the email said: "**Differences Pilot Training:** Ensuring that the level of change on the MAX keeps the Differences training to 16 hours or less of Level B training. Concerns include the impact of the

[884] Mark Forkner's LinkedIn page, accessed here: https://www.linkedin.com/in/mark-forkner-652355103
[885] Kyle Arnold, "Test pilot at center of 737 Max investigation takes buyout from Southwest Airlines," *The Dallas Morning News*, August 7, 2020, accessed here: https://www.dallasnews.com/business/airlines/2020/08/07/test-pilot-at-center-of-737-max-investigation-takes-buyout-from-southwest-airlines
[886] Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020, and Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.
[887] Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020.
[888] Ibid.
[889] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.
[890] Ibid.
[891] Ibid.

resolution of 25.1322 trade[892] and the Autopilot roll saturation change driven by the addition of MCAS to the flight controls system."[893]

Mr. Teal said he did not recall the concern about MCAS but did recall a concern that the Roll Control Alerting System (RCAS) on the airplane "potentially had the act of requiring higher than level B training."[894] However, a little more than two weeks after Mr. Teal sent his May 2013 email about MCAS and "pilot differences training," several Boeing employees had a meeting to specifically discuss MCAS and the impact it could have on pilot training and certification requirements for the 737 MAX aircraft.[895] An email summarizing that meeting said, "If we emphasize MCAS is a new function there may be greater certification and training impact."[896] In his interview, Mr. Teal said he was unaware of this meeting.[897]

Regardless, it is clear that MCAS **did** pose a risk to Level B non-simulator training and that it **was** a concern inside Boeing. However, it was not the only system on the MAX that posed a risk to Level B training requirements and endangered Boeing's "no simulator" goal for MAX pilots.

Pushing Back on Level B

For its part, the FAA's Seattle Aircraft Evaluation Group (AEG) recognized that the 737 MAX was a complex modification to Boeing's predecessor model airplane, the 737 NG, that incorporated many "substantial systems changes due to new certification requirements."[898] In a May 10, 2015, internal email concerning this issue, an official in the Seattle AEG that would determine pilot training requirements wrote that "[t]he B737MAX presents some very contentious issues between Boeing and the FAA that will likely heat-up as we approach rollout and evaluation of the aircraft."[899] Further, this official said, "[w]e have reason to believe that Boeing's assessment of B

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[892] This is a reference to the FAA's Advisory Circular number 25.1322-1 on "Flightcrew Alerting" that provides guidance for showing compliance with certain requirements of Title 14 of the Code of Federal Regulations (14 CFR), part 25, for the design approval of flightcrew-alerting functions. See "Subject: Flightcrew Alerting," Advisory Circular, AC No: 25.1322-1, Federal Aviation Administration, Department of Transportation, December 13, 2010, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25.1322-1.pdf

[893] Boeing internal email from former 737MAX Chief Project Engineer to Boeing Commercial Airplanes (BCA) Senior Chiefs and Functional Leaders, "Subject: 737MAX Firm Configuration Status/Help Needed," Sent: May 4, 2013, 11:35:58 AM, BATES Number TBC-T&I049683-049684. (On file with the Committee).

[894] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.

[895] Boeing "ITRACS" report, "Title: MCAS/Speed Trim," 37MAXFCI-PDR_AI22, Item entered: May 21, 2013, Item closed: June 27, 2013, BATES Number TBC-T&I 549172 – 549173. (On file with the Committee).

[896] Boeing internal email, "Subject: PRG – 37MAXFCI-PDR_AI22 – MCAS/Speed Trim," June 7, 2013, 9:13:10 PM, accessed at p. 93 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[897] Committee staff transcribed interview of Michael Teal, Boeing Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.

[898] FAA Memorandum, From: Seattle Aircraft Evaluation Group (SEA-AEG), To: Flight Standards, "Subject: Boeing 737 MAX Type Rating Determination and Pilot Training Requirements," May 10, 2015, BATES Number, FAA-DEFAZIO-000032887-32890, accessed at p.231 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[899] FAA internal email, "Subject: RE: 737 MAX training question," Sent: May 10, 2015, 1:44 PM, BATES Number FAA-DEFAZIO-000032884, accessed at p. 228 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Level training differences (Computer Based Training) between the MAX and NG will be insufficient."[900]

Attached to that email, the AEG official included a memorandum that outlined the AEG's concerns regarding the possible need for simulator training on the 737 MAX as a result of several planned systems that were to be included on the aircraft.[901] The memo listed six separate systems that could require increased pilot training requirements.[902] These included Fly-by-wire (FBW) Spoilers, Direct Lift Control, Landing Attitude Modifier (LAM), Roll Command Alerting System (RCAS), Max Display System, and Environmental Control System (ECS).[903] Interestingly, MCAS was not listed at the time.

The AEG had serious concerns about Boeing's aggressive and contentious efforts to avoid simulator training on the MAX, but in 2015 that focus was on other systems on the aircraft and not MCAS. In fact, Boeing's description of MCAS as just an addition to the Speed Trim System and the operational parameters of MCAS **before** it was redesigned did not give AEG officials much pause. They remained unaware of Boeing's dramatic redesign of MCAS in March 2016 that gave the system much greater authority to control the aircraft until **after** the Lion Air crash.[904] Had they known of those changes to MCAS prior to certification, it may have altered their assessment of the aircraft.

Memo from Seattle AEG Manager to FAA, Director, Flight Standards May 10, 2015

"FOR THE PAST 3 YEARS, BOEING HAS CONTINUALLY ARGUED WITH THE BASOO THAT THEY CANNOT MEET THE LATEST AMENDMENTS TO AIRCRAFT CERTIFICATION REGULATIONS DUE TO THE IMPACT ON FLIGHT CREW TRAINING."

Also included in the Seattle AEG's May 2015 memorandum concerning the effect of the MAX's new systems on training requirements, the author stressed that although Boeing had been consistently pushing for minimal Level B differences training for pilots currently qualified on the 737 NG, the FAA might have to require higher-level simulator training.[905] The memo expressly pointed out the negative impact Boeing's goal of no simulator training was having on Boeing's ability to meet Federal aviation regulations.[906] "For the

[900] Ibid.
[901] FAA Memorandum, From: Seattle Aircraft Evaluation Group (SEA-AEG), To: Flight Standards, "Subject: Boeing 737 MAX Type Rating Determination and Pilot Training Requirements," May 10, 2015, BATES Number, FAA-DEFAZIO-000032887-32890, accessed at p.231 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[902] Ibid.
[903] Ibid.
[904] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Department of Transportation, Office of Inspector General, Report No. AV2020037, June 29, 2020, pp. 21-22, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf
[905] FAA Memorandum, From: Seattle Aircraft Evaluation Group (SEA-AEG), To: Flight Standards, "Subject: Boeing 737 MAX Type Rating Determination and Pilot Training Requirements," May 10, 2015, BATES Number, FAA-DEFAZIO-000032887-32890, accessed at p.231 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[906] Ibid.

past 3 years, Boeing has continually argued with the BASOO that they cannot meet the latest amendments to aircraft certification regulations due to the impact on flight crew training," the memo said.[907]

The memo also laid out the AEG's concerns with Boeing's approach to training. "It is Boeing's intention not to have a task trainer or simulator to train pilots between the NG and the MAX; The SEA AEG disagrees with this assessment," the memo said.[908] The memo listed the six systems cited above as potentially requiring additional pilot training. In particular, the memo highlighted three systems that were likely to require simulator training. Regarding the Direct Lift Control system, the memo said: "It is the opinion of the AEG that this system will need to have a full flight simulator to train the pilots."[909] On the Landing Attitude Modifier (LAM), the memo indicated: "Only a full flight simulator can be used for takeoff and landing credit." Additionally, regarding the Enhanced Bank Angle Warning (EBAW) system, that is part of the Roll Command Alerting System (RCAS), the memo said: "This is highly integrated system that may require simulator training."[910]

Memo from Seattle AEG Manager to FAA, Director, Flight Standards May 10, 2015

"IT IS BOEING'S INTENTION NOT TO HAVE A TASK TRAINER OR SIMULATOR TO TRAIN PILOTS BETWEEN THE NG AND THE MAX; THE SEA AEG DISAGREES WITH THIS ASSESSMENT.

….

IT IS COMMON PRACTICE FOR THE MANUFACTURER TO REQUEST MINIMAL PILOT TRAINING DUE TO THE COST IMPACT FOR THEIR CUSTOMERS."

The AEG memo also pointed out: "It is common practice for the manufacturer to request minimal pilot training due to the cost impact for their customers."[911] Despite its concerns, in the end, the FAA did not require simulator-based training for any of these systems. The FAA believed that Boeing had satisfactorily resolved all of their concerns.

Safety and Commonality

In his interview with Committee staff, Mr. Leverkuhn claimed that the objective to avoid simulator training requirements was not about cost, but about safety. Boeing realized they could not obtain "a common type rating between the [737] classic, the NG, and the MAX," he said.[912] "Ultimately, it was determined that that just was not going to be possible because the changes between those three, particularly, the classic, were too significant to expect the pilot to be able to, for instance, operate all three on any given day. And that was a determination made not only by the FAA but certainly internally at Boeing as well," said Mr. Leverkuhn.[913] "So the commonality

[907] Ibid. Note that the BASOO is the Boeing Aviation System Oversight Office based in Seattle, Washington, and is FAA's office charged with overseeing Boeing's certification compliance on all Boeing commercial aircraft.
[908] Ibid.
[909] Ibid.
[910] Ibid.
[911] Ibid.
[912] Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020.
[913] Ibid.

approach is to assure that when a pilot flies an airplane for which he is type rated and knowing that there is a possibility of flying on, you know, flying from Houston to Kansas City on an NG, and then from Kansas City to Detroit on a MAX, does the airplane have the same look, feel, flying characteristics, handling characteristics so that the pilot is not having to constantly remember, you know, which airplane he might be flying on?"[914]

For his part, Mr. Teal argued that the "commonality" between the 737 NG and the 737 MAX made the planes safer to fly and that greater than Level B training simply was not needed. "To me, this is a safety conversation. It's not about the dollars and cents associated with what I consider a minor cost of the … training differences. It's about the safety aspect," said Mr. Teal.[915] However, he also suggested that if a regulator had required an "additional level of training" it would have indicated "that we have failed in meeting our requirements of having a safe airplane…."[916]

Human factors experts, particularly in the wake of the MAX crashes and the revelations about the flaws in MCAS's technical design issues, have emphasized the need for simulator training on new features on new or derivative model aircraft. In testimony to the Committee in December 2019, Dr. Mica Endsley, a Committee Chair at the Human Factors and Ergonomics Society and a former Chief Scientist of the United States Air Force, described the importance of pilot simulator training, particularly to familiarize pilots with new automation-related technologies, such as MCAS.

> New automation should be introduced with training to allow pilots to develop accurate mental models of how it works, an understanding of its limitations and reliability in different situations, and information on how to detect and recover from abnormal events and failure conditions. As a significantly new piece of automation that had a direct effect on aircraft control, experiential training (e.g. via simulations) should have been provided that would allow pilots to experience MCAS operations, its failure conditions, and to perform the tasks needed to recover from and effectively overcome abnormal conditions.[917]

Unfortunately, Boeing's Level B (non-simulator) training goals and the FAA's ultimate decision granting Level B training on the MAX undermined the best practices training procedures outlined by Dr. Endsley. In 2016, the Seattle AEG proceeded with flight testing of the MAX via its Flight Standardization Board, and on August 17, 2016, informed Boeing of its determination concerning pilot training requirements.[918] In a decision highly favorable to Boeing, the AEG said that after running its flight tests it determined that Level B differences training would be required for

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[914] Ibid.
[915] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.
[916] Ibid.
[917] Prepared statement of Dr. Mica R. Endsley, Human Factors and Ergonomics Society, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/committee-activity/hearings/the-boeing-737-max-examining-the-federal-aviation-administrations-oversight-of-the-aircrafts-certification
[918] FAA letter to The Boeing Company, "Subject: Boeing 737 MAX Pilot Qualification Plan (PQP) Gate 4," August 17, 2016, BATES Number TBC-T&I 010895 (On file with the Committee).

pilots seeking to transition from the 737 NG to the MAX.[919] Thus, no simulator training would be required to transition from flying the 737 NG to flying the 737 MAX aircraft.

Obtaining Level B training on the MAX was a huge victory for Boeing. On Tuesday, August 16, 2016, one day prior to the official FAA letter granting this provisional approval, Mr. Forkner, the 737 Chief Technical Pilot, sent an email to 40 Boeing employees and supervisors, including Mr. Leverkuhn and Mr. Teal, announcing this achievement.[920] The subject line on the email said: "Subject: MAX Differences Training approved at Level B!!!!!" The email expressed a sense of jubilation in obtaining Level B training on the MAX. Mr. Forkner wrote:

> This culminates more than 3 years of tireless and collaborative efforts across many business units. Flight Technical, Flight Technical Data, Training Development, Flight Deck Crew Ops, All MAX engineering teams, Flight Test Engineering and of course [redacted] Engineering Test Pilot team all should be commended for their efforts in getting us to the finish line.[921]

One excited Boeing colleague emailed Mr. Forkner: "And, just to confirm, there are absolutely no formal checks? And, no functional currency issues between the NG and MAX … you can be away from the NG for 30-years and still be able to jump into a MAX? LOVE IT!"[922] Mr. Forkner responded: "… No special currency issues or formal checks of any sort were identified by the regulators. That's the whole point of Level B."[923]

Boeing Will Not Allow That to Happen

Obtaining Level B training must have come as a tremendous relief to Mr. Forkner. It is clear from emails and instant messages provided to the Committee by Boeing that Mr. Forkner was under tremendous pressure to ensure Boeing achieved Level B training on the MAX. In a December 2014 email to a Boeing colleague, 20 months prior to the FAA's decision on the MAX's training requirements, Mr. Forkner expressed concern based on his responsibility to coordinate training requirements with the FAA's Flight Standardization Board. "[I]f we lose Level B," he wrote, the blame "will be thrown squarely on my shoulders," conveying his feeling that he would be held

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[919] Ibid.
[920] Boeing internal email, "Subject: MAX Differences Training approved at Level B!!!!!," Sent: Tuesday, August 16, 2016, 2:48 PM, BATES Number TBC-T&I 010893 – 010894, at pp. 139-140, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[921] Ibid.
[922] Boeing internal email, "Subject: RE: Differences Training approved at Level B!!!!!," Sent: Tuesday, August 16, 2016, 3:43 PM, accessed at p. 12 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[923] Boeing internal email, "Subject: RE: Differences Training approved at Level B!!!!!," Sent: Wednesday, August 17, 2016, 1:43 PM, accessed at pp. 11-12 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

personally responsible by Boeing's leadership for the financial consequences of not obtaining Level B training.[924]

Mr. Forkner's emails and instant messages show how closely intertwined the Level B (non-simulator) training goal was with technical decisions that affected training. In July 2014, for example, the Level B training goal overshadowed discussions Mr. Forkner had with a colleague concerning the development of pilot checklists for the Flight Crew Training Manual. As related to the specific checklists they were developing, Mr. Forkner advised that they follow "the path with the least risk to Level B" and "sell" an action pertaining to trim technique as a "very intuitive basic pilot skill."[925]

Mr. Forkner's colleague cautioned: "I fear that skill is not very intuitive any more with the younger pilots and those who have become too reliant on automation."[926]

Mr. Forkner responded: "Probably true, but it's the box we're painted into with the Level B training requirements."[927]

The pressure to achieve Level B training also was evident in Mr. Forkner's disdain for FAA's AEG, which would ultimately determine training requirements. In May 2015, Mr. Forkner derided the AEG in instant messages with a Boeing colleague in which he described a briefing to the AEG on the 737 MAX. "[I]t was like dogs watching TV for the AEG (and me too) curves, slopes, graphs, blah blah blah, stuff non-engineers and test pilots can't really understand other than the lines all line up between max and NG, which is supposed to prove they fly the same."[928]

In November 2015, Mr. Forkner also wrote about the need to "push back very hard" against the AEG regarding potential simulator training requirements and said he "will likely need support at the highest levels" at Boeing in negotiating with the FAA regarding such requirements for the 737 MAX's Roll Command Alerting System (RCAS). "Failure to obtain Level B training for RCAS is a planet-killer for the MAX," wrote Mr. Forkner.[929]

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[924] Boeing internal email, "Subject: RE: Tomorrow," December 18, 2014, 12:28:37 PM, accessed at p. 6 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[925] Boeing internal email, "Subject: RE: RCAS testing of training," Sent: Tuesday, July 22, 2014, 8:27 PM, p. 3-4, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[926] Boeing internal email, "Subject: RE: RCAS testing of training," Sent: Wednesday, July 23, 2014, 7:11 AM, p. 3, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[927] Boeing internal email, "Subject: RE: RCAS testing of training," Sent: July 23, 2014, 7:43:41 PM, p. 3, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[928] Instant Message from 737 Chief Technical Pilot to Boeing staff, Sent: May 29, 2015, 8:08 AM, BATES Number: TBC-T&I 549002 (On file with the Committee).

[929] Boeing internal email, "Subject: RE: !!! Important Help Needed!!!EASA RSAT/RCAS ECD dates," Sent: Tuesday, November 17, 2015, 2:21 PM, p. 90, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

7. Boeing 737 MAX Pilot Training

Once the FAA obviated the need for simulator-based differences training on the MAX in August 2016, a decision that largely affected U.S. airlines, and after the MAX was certified in March 2017, Boeing aggressively discouraged foreign-flagged airlines from setting their own simulator training requirements. In particular, emails from Mr. Forkner concerning the company's foreign airline customers show strong opposition to simulator training and grossly inappropriate language in reacting to airlines that even inquired about simulator training needs for their MAX pilots. Mr. Forkner also boasted that his efforts to talk airlines out of simulator training was of significant financial benefit to Boeing.

For example:

- In response to a March 2017 request from Boeing's Africa & Caribbean Sales Director related to an inquiry from a customer airline about costs to provide training to its flight crews, Mr. Forkner wrote: "I want to stress the importance of holding firm that there will not be any type of simulator training required to transition from the NG to the MAX. Boeing will not allow that to happen. We'll go face to face with any regulator who tries to make that a requirement."[930]

- In June 2017, in response to an airline that was considering simulator-based training for its pilots transitioning to the MAX, Mr. Forkner wrote in an email, "There is absolutely no reason to require your pilots to require a MAX simulator to begin flying the MAX. Once the engines are started, there is only one difference between NG and MAX procedurally, and that is that there is no OFF position of the gear handle. Boeing does not understand what is to be gained by a 3 hour simulator session, when the procedures are essentially the same."[931] … "A simulator training requirement would be quite burdensome to your operation," wrote Mr. Forkner in a separate email.[932]

- In a separate instant message exchange with a Boeing colleague, also in June 2017, Mr. Forkner wrote: "Now friggin Lion Air might need a sim to fly the MAX, and maybe because of their own stupidity. I'm scrambling to figure out how to unscrew this now! idiots"[933] That same month Mr. Forkner emailed a colleague, "I'm putting out fires with the [redacted] who suddenly think they need simulator training to fly the MAX! ARGGGGGGGGGGGGGGGGGGGGGGGGGGGGGHHHHH!!!!!!!!!!"[934]

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[930] Boeing internal email, "Subject: RE: Flight Transition costs," March 28, 2017, 9:00:58 AM, accessed at p. 28 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[931] Boeing email to airline customer, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Tuesday, June 6, 2017, 11:01:40 AM, accessed at p. 34 and p. 60 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[932] Boeing email to airline customer, "Subject: RE: MAX LEVEL B DIFFERENCES SOLUTION," Sent: Monday, June 5, 2017, 10:59 PM, accessed at p. 33 and p. 59 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[933] Boeing internal instant message, Sent: June 5, 2017, 6:57 PM, BATES Number TBC-T&I 549015. (On file with the Committee).

[934] Boeing internal email, "Subject: RE: 737 MAX ATB/RTL FOTB," Sent: Monday, June 5, 2017, 8:01 PM, accessed at p. 14 here:

- In December 2017, Mr. Forkner informed a colleague in an instant message exchange that he made a foreign airline "feel stupid about trying to require any additional training requirements." "… I just jedi mind tricked this [sic] fools," Mr. Forkner wrote. "I should be given $1000 every time I take one of these calls," he said, and then added "I save this company a sick amount of $$$$"[935]

Pressuring Airlines

Mr. Leverkuhn and Mr. Teal both claimed in interviews with Committee staff that they were unaware of these communications at the time.[936] They also both claimed that they were unaware of Mr. Forkner's efforts to pressure Boeing's customer airlines out of simulator training.

Boeing's 737 Chief Technical Pilot, Internal Email March 28, 2017

"I WANT TO STRESS THE IMPORTANCE OF HOLDING FIRM THAT THERE WILL NOT BE ANY TYPE OF SIMULATOR TRAINING REQUIRED TO TRANSITION FROM THE NG TO THE MAX. BOEING WILL NOT ALLOW THAT TO HAPPEN. WE'LL GO FACE TO FACE WITH ANY REGULATOR WHO TRIES TO MAKE THAT A REQUIREMENT."

Neither Mr. Teal nor Mr. Leverkuhn had a supervisory role over Mr. Forkner, who reported through a different chain within Boeing. However, Mr. Forkner worked closely with the MAX program. In his interview with Committee staff, Mr. Teal said he was unaware of Mr. Forkner acting unprofessionally or inappropriately and said he did not recall anyone complaining about Mr. Forkner or him being reprimanded or disciplined in any way.[937] For his part, Mr. Leverkuhn said: "I didn't have any issues raised with Mark."[938]

The offensive and inappropriate language Mr. Forkner used in his emails and instant messages was highly disturbing. Since they were released, Boeing has condemned these communications. In January 2020 Boeing released a statement that said, in part:

> We regret the content of these communications, and apologize to the FAA, Congress, our airline customers, and to the flying public for them. We have made significant changes as a company to enhance

https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[935] Boeing internal instant message, December 12, 2017, BATES Number TBC-T&I 549024-549025. (On file with the Committee).

[936] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020, and Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020.

[937] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes, May 11, 2020.

[938] Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020.

> our safety processes, organizations, and culture. The language used in these communications, and some of the sentiments they express, are inconsistent with Boeing values, and the company is taking appropriate action in response. This will ultimately include disciplinary or other personnel action, once the necessary reviews are completed.[939]

There is absolutely no excuse for the language used in these communications, and it is deeply troubling that Boeing employees pushed back on the pilot training concerns of their customers that may have affected the safety of their airlines. In February 2020, *Bloomberg* reported that Boeing put three employees who worked with the company's former 737 Chief Technical Pilot (Mark Forkner) on administrative leave regarding their involvement in those communications.[940]

However, Mr. Forkner's hard sell tactics to dissuade airlines from simulator training was the result of an implied message from Boeing management to discourage such training because of the threat it posed to the marketing strategy and ultimately the profitability of the 737 MAX program.

In fact, the Committee has learned that in September 2016, one month after the FAA provided Boeing with provisional approval for Level B (non-simulator) training for 737 MAX pilots, Mr. Forkner and his team of technical pilots that had been promoting Level B training were granted an award for their efforts from Boeing. An internal Boeing email said that the technical pilot team received the company's Commercial Aviation Services (CAS) Service Excellence Award on September 14, 2016, "along with the Training Development Team for their role is [sic] developing the MAX Level B differences training which was approved by the FAA."[941] The Committee has confirmed that at least one of those who received this award was one of the three individuals Boeing put on administrative leave earlier this year.

737 MAX Simulator Discrepancy Reports and Schedule Pressure

While Boeing successfully convinced the FAA not to require MAX simulator training for those pilots transitioning between the 737 NG and 737 MAX aircraft, flight simulators are part and parcel of the aircraft development process and the continued operational requirements of commercial aircraft in general. They help to replicate potential flight conditions for the manufacturer during the certification process and for customer airlines during routine training of their pilots. The use of simulators can reduce costs on fuel and maintenance because pilots are not actually flying the aircraft. They can also simulate a wide range of conditions to both test the pilots' flying abilities and to observe or tweak technical features on the aircraft.[942]

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[939] "Boeing Statement on Employee Messages Provided to U.S. Congress and FAA," Boeing, January 9, 2020, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130600%20

[940] Peter Robison, Julie Johnsson and Alan Levin, "Boeing Suspends Co-Workers of Pilot at Center of Max Scrutiny," *Bloomberg*, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-22/boeing-suspends-co-workers-of-pilot-at-center-of-max-scrutiny

[941] Boeing internal email, "Subject: RE: Weekly inputs," September 21, 2016, 4:26 PM, BATES Number TBC T&I TBC-T&I 552192. (On file with the Committee).

[942] See: "The perfect illusion: Technology of full flight simulators," *ProFlight,* accessed here: https://www.proflight.com/en/full-flight-simulatoren/technologie.php

7. Boeing 737 MAX Pilot Training

In the case of Boeing and the 737 MAX aircraft, as with virtually all other commercial aircraft, flight simulators were necessary as a normal tool to help familiarize potential customer airlines with the MAX and to help maintain routine training credentials of pilots. With support from its supplier,[943] Boeing operates an entire division that provides pilot training and simulator management and support services for customer airlines.[944] The FAA also has a role in setting flight simulator requirements and assessing their performance.[945] In May 2016, for instance, new FAA regulations went into effect amending previous standards for flight simulators.[946]

But like the aircraft itself, Boeing's MAX simulators had problems. In the spring of 2018, for instance, more than one year after the MAX received its type certification from the FAA, Boeing emails and instant messages show that Boeing employees had serious concerns about the quality of the MAX simulators. They were also deeply troubled by Boeing's poor management of the simulator program, lack of adequate engineering support, and schedule pressure that they felt was driving a rushed process resulting in mistakes and apprehension about the quality of the simulators. For example:

- In February 2018, a Boeing employee said there were 180 discrepancy reports (DRs) with the MAX simulator in England at its London Gatwick (LGW) site.[947] "Honesty is the only way in this job – integrity when lives are on the line on the aircraft and training programs shouldn't be taken with a pinch of salt," wrote one frustrated Boeing employee.[948] "Would you put your family on a MAX simulator trained aircraft? I wouldn't," he said to his colleague, who answered: "No."[949]

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[943] "TRU Delivers First Ever Boeing 737 MAX Full Flight Simulator," Press Release, TRU Simulation + Training, November 2, 2017, accessed here: https://www.trusimulation.com/media-hub/tru-delivers-first-ever-boeing-737-max-full-flight-simulator. TRU Simulation + Training, based in Goose Creek, South Carolina, is a subsidiary of Textron Inc. The company has a 10-year exclusive agreement with Boeing to provide multiple 737 MAX full flight training suites to Boeing's training campuses worldwide.

[944] See: Boeing Simulator Management, accessed here: https://www.boeing.com/commercial/services/training-and-resourcing/simulator-management.page and Boeing Simulator Services, accessed here: https://www.boeing.com/commercial/services/flight-operations-solutions/simulator-services

[945] See "Flight Simulation Training Device Qualification Standards for Extended Envelope and Adverse Weather Event Training Tasks, Final Rule" Department of Transportation, Federal Aviation Administration, 14 CFR Part 60, published in Federal Register, Vol. 81, No. 61, March 30, 2016, accessed here: https://www.federalregister.gov/documents/2016/03/30/2016-05860/flight-simulation-training-device-qualification-standards-for-extended-envelope-and-adverse-weather

[946] Ibid.

[947] Boeing internal instant messages, "Subject: Conversation with [redacted]," February 8, 2018, 8:25:29 PM, accessed at p. 102 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

[948] Ibid, p. 103.

[949] Ibid, p. 103.

- In March 2018, the issue of high numbers of discrepancy reports on the MAX simulators was still a major issue. "It's a bloody joke," quipped one Boeing employee.[950] "They do not understand the liability we as a company are taking on," he wrote.[951]

- In April 2018, a Boeing employee lamented: "This is a direct result of a pour [sic] plan which I objected to repeatedly since day 1. The schedule simply did not permit for any corrective actions to be taken…"[952] A colleague responded: "I agree with you entirely and agree with the whole failure to plan this program properly from the Boeing side."[953] In a separate exchange that same month a Boeing employee observed that the flight simulator was pitching his colleague into a stall and then added, "We have been trying to fix that for over 6 months."[954]

- In May 2018, a frustrated Boeing employee mentioned it took six hours to resolve the large number of deficiency reports and complained about Boeing management pushing forward despite the problems. "[T]hey are ploughing forward regardless of the danger, failing to appreciate the implication of Boeing failing to qualify a Boeing device…" he wrote. "They are failing to appreciate that a delay would be less costly than the incurred costs…."[955]

In response to these and other communications that it provided to Congress, and the Committee made public in January 2020, Boeing said in a statement:

> These communications contain provocative language, and, in certain instances, raise questions about Boeing's interactions with the FAA in connection with the simulator qualification process.
>
> Having carefully reviewed the issue, we are confident that all of Boeing's MAX simulators are functioning effectively. The

[950] Boeing internal instant messages, "Subject: Conversation with [redacted]," March 22, 2018, 9:25 AM, accessed at p. 74 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[951] Ibid, p. 75.
[952] Boeing email, "Subject: RE: Updated QTG," April 24, 2018, 23:33, accessed at p. 105 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[953] Boeing email, "Subject: RE: Updated QTG," April 24, 2018, 4:02:27 PM, p. 105, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[954] Boeing internal instant message, "Subject: Testing of TP 2.3.57 / Binary 3.19.4.0a," April 8, 2018, 8:10:13 AM, accessed at p. 98 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[955] Boeing internal instant message, "Subject: Conversation with [redacted]," May 15, 2018, 12:09:52 PM, accessed at p. 97 here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

> qualification activities referenced in these communications occurred early in the service life of these simulators.[956]

It is worth noting that the simulator incidents described above all occurred roughly one year or more **after** the 737 MAX was certified by the FAA.

Reverse Course

By Boeing's own actions, it has acknowledged multiple failures on the 737 MAX, although it has been reluctant to articulate those facts publicly. The changes it has said it will make or has already made to the 737 MAX, however, are a tacit confession of the program's original failings. Boeing has redesigned MCAS to rely on two AOA sensors and to not activate repeatedly. In addition, Boeing has fixed the AOA Disagree alert issue. Finally, in January 2020, with two lethal MAX accidents behind them, Boeing reversed course and said it would recommend simulator training for all MAX pilots.[957]

In a short statement on January 7, 2020, Boeing announced:

> Boeing is recommending 737 MAX simulator training in addition to computer based training for all MAX pilots prior to return to service of the 737 MAX. This recommendation takes into account our unstinting commitment to the safe return of service as well as changes to the airplane and test results. Final determination will be established by the regulators.[958]

The *New York Times* reported that, "[t]he decision stems from Boeing's analysis of recent flight simulator tests that were part of the work necessary to return the Max to service, which showed that pilots were not using the right procedures to handle emergencies."[959] It is important to remember, as described in this report's previous discussion of MCAS, that Boeing was aware of slow pilot reaction times that could jeopardize the safety of the MAX well before the airplane was certified.[960]

In 2012, Boeing had evidence from its own test pilot that some pilots may not respond rapidly enough to successfully counter uncommanded MCAS activation, a condition Boeing's test

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[956] "Boeing Statement on Employee Messages Provided to U.S. Congress and FAA," Boeing News Release, January 9, 2020, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130600%20
[957] "Boeing Statement on 737 MAX Simulator Training," Boeing News Release, January 7, 2020, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130596
[958] Ibid.
[959] Natalie Kitroeff and David Gelles, "In Reversal, Boeing Recommends 737 Max Simulator Training for Pilots," *New York Times*, January 7, 2020, accessed here: https://www.nytimes.com/2020/01/07/business/boeing-737-max-simulator-training.html
[960] See: Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, and Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at pp. 164 and 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

pilot found to be "catastrophic[.]"[961] Rather than fully investigating that issue and determining if greater training requirements might be required to improve those sorts of pilot responses, Boeing essentially explained away the test results, ignored the evidence they had, and chose not to inform the FAA, its customers, or MAX pilots about this internal data—because it was not required to be shared, according to Boeing's interpretation of Federal regulations.

Fear of being forced to accommodate simulator training requirements was prevalent throughout the MAX program. This had an overriding impact on design decisions—avoiding changes that could potentially lead the FAA to require simulator training even if these design enhancements improved safety. A May 2019 article in *Bloomberg* titled: "Former Boeing Engineers Say Relentless Cost-Cutting Sacrificed Safety," pointed out that, "The failures of the 737 Max appear to be the result of an emphasis on speed, cost, and above all shareholder value."[962] Some of the former Boeing engineers interviewed for the article noted how Boeing's desire not to have simulator training had a detrimental impact on the MAX's engineering decisions. One former employee said that internal Boeing performance reviews focused on cost savings and not safety. The article emphasized that corporate pressure regarding simulator training on the MAX is "essential to understanding how an emphasis on costs twisted a process that's supposed to produce the best, safest planes."[963] The Committee's investigation has revealed similar findings.

Boeing's recent decision to recommend simulator training for all MAX pilots is appropriate and long overdue. However, it was a clear and stunning admission that its previous assumptions about pilot training requirements were inaccurate and inadequate. In addition, the efforts to obtain Level B training requirements did not just limit pilot training, they hindered the inclusion of technologies on the MAX that may have improved safety.

In the push to produce an economically and operationally viable aircraft to compete with Airbus's A320neo, Boeing undermined safety, tarnished its reputation, and as a result of the MAX's grounding, created severe financial consequences for its customer airlines and for itself.[964] Most importantly, these combined actions and faulty assumptions led to two tragic accidents and the death of 346 people.

The problems that enveloped the 737 MAX program were not isolated to the design and development of the aircraft. Once the aircraft was certified by the FAA in March 2017 and the MAX began rolling off of Boeing's production line in Seattle, Washington, other issues began to emerge.

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[961] Internal Boeing email, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 1:41 PM, BATES Number TBC-T&I 131226 – 131227. (On file with the Committee).
[962] Peter Robison, "Former Boeing Engineers Say Relentless Cost-Cutting Sacrificed Safety," *Bloomberg,* May 9, 2019, accessed here: https://www.bloomberg.com/news/features/2019-05-09/former-boeing-engineers-say-relentless-cost-cutting-sacrificed-safety
[963] Ibid.
[964] Dominic Rushe, "Boeing puts cost of 737 Max crashes at $19bn as it slumps to annual loss," *The Guardian*, January 29, 2020, accessed here: https://www.theguardian.com/business/2020/jan/29/boeing-puts-cost-of-737-max-crashes-at-19bn-as-it-slumps-to-annual-loss and Darryl Campbell, "The 737 Built Southwest, and the 737 MAX Could Be its Undoing," *The Verge*, October 23, 2019, accessed here: https://www.theverge.com/2019/10/23/20927213/boeing-737-max-southwest-planes-crash-budget-airlines-grounded-cost-maintenance

8. Production Pressure

-Production Pressure -

INVESTIGATIVE FINDINGS

- The 737 MAX program was launched under intense financial pressure to aggressively compete with Airbus' new A320neo aircraft.[965]
- The MAX became the fastest selling aircraft in Boeing's history with more than 5,000 orders at its peak in 2018.[966]
- Boeing's historic marketing success of the 737 MAX created enormous production pressure that negatively impacted its workforce and the quality and safety of the MAX program.[967]
- To emphasize that sticking to the production schedule was of the utmost priority, senior Boeing management installed "Countdown Clocks" in their conference room in order to make employees on the MAX program aware of key markers in the MAX's development schedule.[968]
- The Committee has learned that when the MAX completed its first flight in January 2016,[969] Michael Teal, Boeing's Chief Project Engineer on the 737 MAX program, received restricted stock options from Boeing to show appreciation for his efforts on the MAX program.[970]
- Boeing's focus on reducing costs and meeting the production schedule resulted in excluding some technologies that may have improved the safety of the 737 MAX, such as synthetic airspeed.[971]

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[965] David Gelles, Natalie Kitroeff, Jack Nicas and Rebecca R. Ruiz, "Boeing Was 'Go, Go, Go' to Beat Airbus With the 737 MAX," *New York Times*, March 29, 2019, accessed here: https://www.nytimes.com/2019/03/23/business/boeing-737-max-crash.html

[966] See: Brianna Gurciullo and Patterson Clark, "What You Need to Know About the Boeing 737 MAX Grounding," *PoliticoPro*, July 2020, accessed here: https://subscriber.politicopro.com/datapoint/2020/07/pro-analysis-what-you-need-to-know-about-the-boeing-737-max-grounding-101374 and Avie Schneider, "Boeing 737 Max, Involved In 2 Crashes, Is Fastest-Selling Plane in Company's History," *National Public Radio (NPR)*, March 11, 2019, accessed here: https://www.npr.org/2019/03/11/702211493/boeing-737-max-involved-in-two-crashes-is-fastest-selling-plane-in-companys-hist

[967] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 74-77: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[968] Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes (BCA), May 19, 2020.

[969] "737 MAX Completes Successful First Flight," The Boeing Company, January 30, 2016, accessed here: https://www.boeing.com/commercial/737max/first-flight/#/overview

[970] Committee staff interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager of the 737 MAX Program, Boeing Commercial Airplanes (BCA), May 11, 2020 and Boeing clarification.

[971] See: Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, at p. 1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production pdf, Natalie Kitroeff, David Gelles and Jack Nicas, "Boeing 737 Max Safety System Was Vetoed, Engineer Says," *New York Times*, October 2, 2019, (Updated 29, 2019), accessed here: https://www.nytimes.com/2019/10/02/business/boeing-737-max-crashes.html and Dominic Gates, Steve Miletich and Lewis Kamb, "Boeing rejected 737 MAX safety upgrades before fatal crashes, whistleblower says," *Seattle Times*,

INVESTIGATIVE FINDINGS - Continued

- In November 2016, at the height of the development of the 737 MAX, an internal Boeing survey regarding pressure on its Authorized Representatives (ARs), who are supposed to represent the interests of the FAA and not Boeing, found that 39 percent of those surveyed believed they had experienced "undue influence."[972]

- Some of Boeing's web of global suppliers and subcontractors had a difficult time keeping up with the pace of the 737 MAX's production. This resulted in a haphazard production process as workers had to pause the traditionally surgically-precise assembly of some MAX aircraft in order to await delivery of key parts and supplies to complete the aircraft's assembly.[973]

- In June 2018, Ed Pierson, a Boeing plant supervisor at the Renton, Washington, 737 MAX final assembly plant raised dire warnings with Scott Campbell, Boeing's 737 General Manager, regarding safety and quality control issues that he believed were undermining the integrity of the 737 MAX aircraft due to worker fatigue and extreme production pressures.[974] "As a retired Naval Officer and former Squadron Commanding Officer," wrote Mr. Pierson, "I know how dangerous even the smallest of defects can be to the safety of an airplane. Frankly right now all my internal warning bells are going off. And for the first time in my life, I'm sorry to say that I'm hesitant about putting my family on a Boeing airplane."[975]

- In July 2018, five weeks after Mr. Pierson's email, he finally met with Mr. Campbell in Mr. Campbell's office. According to Mr. Pierson's testimony to the Committee, he told Mr. Campbell that in the military they would temporarily halt production if they had the kinds of safety problems that Mr. Pierson was seeing on the MAX factory floor. According to Mr. Pierson, Mr. Campbell responded: "The military isn't a profit-making organization."[976]

October 2, 2019 (Updated October 3, 2019), accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost

[972] Boeing presentation "Undue Pressure: Key Learnings and Next Steps," The Boeing Company, November 2016, accessed here at p. 145: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[973] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 74-77: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[974] Email from Ed Pierson to Scott A. Campbell, "Subject: Recovery Operations & Safety Concerns," Saturday, June 9, 2018 1:32 PM. (Available here: Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, 116th Congress, First Session, U.S. House of Representatives, December 11, 2019, pp. 83-84, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[975] Ibid.

[976] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

INVESTIGATIVE FINDINGS - Continued

- Rather than heeding Mr. Pierson's dire warnings and thoroughly evaluating his safety concerns, Boeing continued to ramp up production.[977] Lion Air flight 610 crashed in October 2018, three months after Mr. Pierson retired early out of frustration that Boeing was not adequately addressing his safety concerns.

737 MAX Production Line

Competitive pressure had a significant and deleterious influence on cost, schedule, and production issues on the 737 MAX program. The MAX followed a 50-year production history of Boeing's 737 model airplane. The combined 737 fleet has flown more than 16.8 billion passengers since the first 737 entered commercial service in 1968.[978] In March 2018, one year after the 737 MAX was certified by the FAA, Boeing employees produced the 10,000th 737 to come off the production line.[979] The 10,000th 737 produced was a 737 MAX that rolled out of Boeing's 737 Renton, Washington, production factory in 2018, setting a Guinness World Record title for the "Most produced commercial jet aircraft model" in history.[980]

In fact, the MAX became the fastest selling airplane model ever built with nearly 4,700 MAX orders[981] from more than 100 global customers by the time of the Lion Air crash in October 2018.[982] Combined orders and deliveries of the MAX peaked at more than 5,000[983] in 2018, with 387 MAX aircraft delivered to Boeing's customers by the time the plane was grounded in March 2019 days after the crash of Ethiopian Airlines flight 302.[984]

An estimated 30-percent of the worldwide commercial airplane fleet flying today were produced at Boeing's Renton plant, which has produced the Boeing 707, 727, 737 and 757

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[977] The Boeing Company, Q2 2018 Earnings Call, July 25, 2018, p. 6, p.12 and p.26, accessed here: https://s2.q4cdn.com/661678649/files/doc_financials/quarterly/2018/q2/2Q18-Earnings-Call-Transcript-Final.pdf

[978] "Renton Production Facility," The Boeing Company, accessed here: https://www.boeing.com/company/about-bca/renton-production-facility.page

[979] Kristen Stephenson, "Boeing celebrates its 10,000th 737 aircraft with a new record," Guinness World Records, March 20, 2018, accessed here: https://www.guinnessworldrecords.com/news/commercial/2018/3/boeing-celebrates-its-10-000th-737-aircraft-with-a-new-record-518888

[980] See: "Renton Production Facility," The Boeing Company, accessed here: https://www.boeing.com/company/about-bca/renton-production-facility.page and Kristen Stephenson, "Boeing celebrates its 10,000th 737 aircraft with a new record," Guinness World Records, March 20, 2018, accessed here: https://www.guinnessworldrecords.com/news/commercial/2018/3/boeing-celebrates-its-10-000th-737-aircraft-with-a-new-record-518888

[981] "737 MAX Global Customers That Have Taken Delivery," The Boeing Company, October 30, 2018, accessed here: https://web.archive.org/web/20181030034621/https:/www.boeing.com/commercial/737max/#/customers

[982] Since the Lion Air crash orders for the 737 MAX have declined. As of June 2020, Boeing had 4,559 MAX orders and had delivered 387 aircraft to its customers. See: "Orders & Deliveries: 737 MAX Summary Through June 2020," The Boeing Company, accessed here: http://www.boeing.com/commercial/#/orders-deliveries

[983] Brianna Gurciullo and Patterson Clark, "What You Need to Know About the Boeing 737 MAX Grounding," *PoliticoPro*, July 2020, accessed here: https://subscriber.politicopro.com/datapoint/2020/07/pro-analysis-what-you-need-to-know-about-the-boeing-737-max-grounding-101374.

[984] "Orders & Deliveries: 737 MAX Summary Through June 2020," The Boeing Company, accessed here: http://www.boeing.com/commercial/#/orders-deliveries. (On this webpage you need to generate a "report" on the 737 MAX, which will produce the "737 MAX Summary Through June 2020," indicating 387 MAX aircraft have been delivered as of June 2020).

aircraft.[985] Today, the Renton plant's 737 production facility covers 1.1 million square feet of factory space,[986] equivalent to 25 acres or 19 football fields.

Boeing's production of a 737 MAX airplane encompasses components from an estimated 600 separate suppliers and hundreds of additional subcontractors.[987] It takes 10 days to assemble a MAX aircraft from the time the airplane's fuselage enters the factory floor.[988] Boeing has an entire online video depicting this complicated and intricate process dubbed "Incredible: The Story of the Boeing Renton Site."[989]

In March 2014, Boeing reached a historic first by producing 42 airplanes of its 737 NG model aircraft in a single month at its Renton factory, a 33 percent increase from its 2010 production levels.[990] Boeing's internal magazine *Frontiers* touted this achievement: "To meet demand, Boeing is producing its best-selling 737 jetliner at rates that once might have seemed unthinkable. … While the focus now is on sustaining that rate, Boeing Commercial Airplanes has scheduled another increase to 47 a month in 2017 and is studying rates beyond that, should the market demand it."[991] Indeed, Boeing's marketing and the market demand for the 737 MAX pushed the industrial conveyor belt of 737 MAX airplanes well beyond that rate. At its peak the Renton final assembly building was producing 52 MAX airplanes per month.[992]

But this herculean pace came with consequences. At times Boeing's multitude of suppliers and subcontractors simply could not keep up. In June 2018, for example, Boeing had more than three dozen partially completed 737 MAX airplanes staged outside of the Renton factory while it awaited the delivery of parts from suppliers to complete the production process.[993] This resulted in "out of sequence" work, which can lead to potential quality and safety issues.[994]

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[985] "Renton Production Facility," The Boeing Company, accessed here: https://www.boeing.com/company/about-bca/renton-production-facility.page
[986] Ibid.
[987] David Slotnick, "Boeing's move to halt 737 Max production could hurt the 600 suppliers that make parts for the plane despite its promise not to cut its own workforce," *Business Insider*, December 17, 2019, accessed here, https://www.businessinsider.com/boeing-737-max-production-halt-suppliers-components-2019-12#:~:text=A%20network%20of%20about%20600,such%20as%20wings%20or%20fuselages
[988] "Renton Production Facility," The Boeing Company, accessed here: https://www.boeing.com/company/about-bca/renton-production-facility.page
[989] "Incredible: The Story of the Boeing Renton Site," The Boeing Company, accessed here: https://www.boeing.com/company/about-bca/renton-tour/index.page
[990] "Record Performance," *Frontiers*, Volume XII, Issue XI, The Boeing Company, April 2014, p. 19, accessed here: http://www.boeing.com/news/frontiers/archive/2014/april/pubData/source/Frontiers%20APRIL14_Complete.pdf
[991] Ibid, p. 16.
[992] See: Dennis Muilenburg testimony, Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 52, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Daniel McCoy, "Analyst sees 737 MAX production restarting at fewer than 20 aircraft per month," *Wichita Business Journal*, January 15, 2020, accessed here: https://www.bizjournals.com/wichita/news/2020/01/15/analyst-sees-737-max-production-restarting-at.html
[993] Email from Ed Pierson to Scott Campbell, "Subject: Recovery Operations & Safety Concerns," Sunday, June 10, 2018, 6:48 AM, p. 83, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[994] Cynthia McFadden, Anna Schecter, Kevin Monahan and Rich Schapiro, "Former Boeing manager says he warned company of problems prior to 737 crashes," *NBC News*, December 9, 2019, accessed here: https://www.nbcnews.com/news/us-news/former-boeing-manager-says-he-warned-company-problems-prior-737-n1098536

Each 737 MAX-8 airplane costs more than $121 million,[995] and Boeing has made an estimated $12 to $15 million per MAX airplane it has sold, according to Moody's credit-rating agency.[996] Given these figures, this has amounted to profits between $624-$780 million per month during the MAX's peak production period.

While the MAX was tremendously profitable for Boeing, this rapid rate of production was troubling to some Boeing employees who were concerned about its impact on the quality and safety of the airplane and the workers assembling the aircraft. But sticking to a tight schedule was not just a concern once the MAX was certified by the FAA and Boeing began to produce it on the assembly line. Schedule pressure was a constant concern of senior Boeing officials during the design and development phases of the MAX as well, and Boeing's leadership made sure that concern was relayed to Boeing's engineers and others designing and developing the 737 MAX aircraft.

Countdown Clock

To remind Boeing employees of how critical sticking to the program's schedule was, Boeing's management introduced "countdown clocks" into the MAX program, and they made certain that they were easy to spot.[997] In a transcribed interview with Committee staff, the former Boeing Vice President and General Manager of the 737 MAX program, Keith Leverkuhn, explained that there were countdown clocks associated with two major 737 MAX milestones—one was "power on" (when the airplane is powered up for the first time in the factory). The second was "first flight,"[998] which occurred on January 30, 2016, as scores of Boeing employees watched and applauded as the 737 MAX took off for the first time.[999]

The "countdown clocks" were located in the conference room where the 737 MAX program's senior-most management held "business performance reviews," "technical review boards," and other meetings.[1000] Mr. Leverkuhn acknowledged that it was his "desire" to install these "countdown clocks."[1001] He suggested that the countdown clocks were "an excitement generator to remind people that we were doing something remarkable on the development of the [737 MAX] program."[1002]

However, Mr. Leverkuhn further acknowledged that the countdown clocks were also about keeping to the MAX's planned production schedule. "[O]ne of the mantras that we had was the value of a day, and making sure that we were being prudent with our time," said Mr. Leverkuhn, "that we were being thorough, but yet, that there was a schedule that needed to be met, and, in fact,

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995 "About Boeing Commercial Airplanes," The Boeing Company, accessed here: http://www.boeing.com/company/about-bca/#/prices
996 Benjamin Zhang, "Here's how much Boeing is estimated to make on each 737 MAX 8 plane," *Business Insider India,* March 13, 2019, accessed here: https://www.businessinsider.com/boeing-737-max-profit-moodys-2019-3
997 Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes (BCA), May 19, 2020.
998 Ibid.
999 "737 MAX Completes Successful First Flight," The Boeing Company, January 30, 2016, accessed here: https://www.boeing.com/commercial/737max/first-flight/#/overview
1000 Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes (BCA), May 19, 2020.
1001 Ibid.
1002 Ibid, p. 38.

again, the importance of what we were doing, because ultimately, this was a product that was going to be flying millions and millions of passengers throughout the sky."[1003]

Michael Teal, the 737 MAX's former Chief Project Engineer and Deputy Program Manager of the 737 MAX program, said the countdown clock was put into place in 2012.[1004] "[I]t was very prevalent to keep everyone on schedule to get the airplane flying," said Mr. Teal.[1005] "I recall that."[1006] The 737 MAX countdown clock was a vivid visual reminder to Boeing's employees—from Boeing's management—that emphasized the need to stay on schedule.

Nevertheless, sticking to the 737 MAX's production schedule was not the only factor that was important to Boeing's management. As with any for-profit business, cost was also a significant element of concern to Boeing's leadership. In the case of the 737 MAX program, these concerns led Boeing's management to decide not to pursue certain technical features that may have improved the safety of the aircraft because they came with increased costs and presented risks to the program's goal that pilots who were transitioning from the 737 NG would not require simulator training.

Synthetic Airspeed

Early in the 737 MAX design and development process, Boeing rejected at least one design proposal by Boeing engineers—equipage of a synthetic airspeed indicator on the 737 MAX--due to alleged cost concerns.[1007] In 2013, a Boeing employee suggested that it would be a challenge to install a synthetic airspeed indicator on the 737 MAX.[1008] However, synthetic airspeed indication was already a basic feature on Boeing's 787 Dreamliner.[1009]

An airplane's instruments normally measure airspeed by measuring the pressure at which air molecules enter small tubes called pitot tubes, which protrude from the left and right sides of the airplane's nose, and comparing those measurements against measurements of "static pressure"—the air pressure in the atmosphere outside the airplane.[1010] If any part of the combined pitot-static

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[1003] Ibid, p. 37-38.
[1004] Committee staff transcribed interview of Michael Teal, former Vice President, Chief Project Engineer & Deputy Program Manager of the 737 MAX program, Boeing Commercial Airplanes (BCA), May 11, 2020.
[1005] Ibid.
[1006] Ibid.
[1007] Natalie Kitroeff, David Gelles and Jack Nicas, "Boeing 737 Max Safety System Was Vetoed, Engineer Says, " *New York Times*, October 2, 2019, accessed here: https://www.nytimes.com/2019/10/02/business/boeing-737-max-crashes.html
[1008] Boeing internal email, "Subject: Synthetic Airspeed," February 26, 2013, p.1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf
[1009] See: Boeing Coordination Sheet, "BCA Strategy for Reducing the Risk of Loss of Control Events," B-E911-FD-13-038, March 3, 2014, BATES Number: TBC-T&I020864 – TBC-T&I020879, at TBC-T&I020876 (On file with the Committee); Tom Dodt, "Introducing the 787," The Boeing Company, September 2011, at pp. 40-41, accessed here: http://www.caf-swisswing.ch/alt/images_fotogalerie/video/20110900BCA_Introducing_the_787__ISASI.pdf; and Natalie Kitroeff, David Gelles and Jack Nicas, "Boeing 737 Max Safety System Was Vetoed, Engineer Says, " *New York Times*, October 2, 2019, accessed here: https://www.nytimes.com/2019/10/02/business/boeing-737-max-crashes.html
[1010] *Pilot's Handbook of Aeronautical Knowledge*, No. FAA-H-8083-25B, at 8-2, Federal Aviation Administration, (2016).

system fails, the airplane's computers can no longer compute airspeed, presenting the risk of a stall or loss of control.[1011]

A synthetic airspeed system addresses that risk by creating a redundancy to the mechanical pitot-static system. This system computes airspeed by "synthesizing" various other independent data points—chiefly a GPS-based measurement of the airplane's speed over the ground, the airplane's angle of attack, the last computed measurement of the angle and speed of winds aloft, and the airplane's pitch attitude and heading.[1012] A synthetic airspeed system solves the problem of a loss of conventional airspeed data and provides pilots with a "stopgap" estimate of airspeed on which they can rely to maintain control of the airplane through landing.

However, because the system relies on AOA data as one datapoint, the system can also be used to assess the reliability of AOA sensors.[1013] In other words, if AOA data is lost but not announced to the pilots because of the absence of an AOA Disagree alert, the pilots could infer from the simultaneous loss of a synthetic airspeed computation that one or both of the AOA sensors had failed. Therefore, it is possible that inclusion of a synthetic airspeed system on the 737 MAX could have provided the Lion Air flight 610 flight crew with another clue to help them deduce that at least one AOA sensor had failed (the pilots of Ethiopian Airlines flight 302 correctly diagnosed the problem). Unfortunately, the request to install synthetic airspeed on the 737 MAX was rejected by Boeing management because its introduction would have been too costly and may have resulted in the FAA requiring simulator training on the MAX – something that would have jeopardized the 737 MAX program's clear and consistent goal to avoid simulator training requirements.[1014]

In February 2013, a Boeing employee emailed a 737 Technical Pilot and wrote: "It will be a challenge to implement synthetic airspeed on the 737" MAX, noting that the implementation would "need to be different from the 787" Dreamliner.[1015] The Technical Pilot responded,

> As I pointed out in the telecom today, an introduction of synthetic airspeed to the MAX would drastically alter [the Airspeed Unreliable] Critical Action, Memory Item Non-Normal Checklist. If synthetic

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[1011] Ibid.; See also: "Final Report on the Accident on 1st June 2009 to the A330-203 Registered F-GZCP Operated by Air France Flight AF 447 Rio de Janeiro-Paris," Bureau d'Enquetes et d'Analyses pour la securite de l'aviation civile, at 31-33, accessed here: https://www.bea.aero/docspa/2009/f-cp090601.en/pdf/f-cp090601.en.pdf

[1012] See:Matt Miltner, Pengfei (Phil) Duan, and Dr. Maarten Uijt de Haag, "Modeling and Utilization of Synthetic Data for Improved Automation and Human-Machine Interface Continuity" (presentation at Digital Avionics Systems Conference), Colorado Springs, Colo., Oct. 5-9, 2014), accessed here: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6979576

[1013] See: Letter from Boeing Employee to the U.S. Senate Commerce, Science, and Transportation Committee, June 5, 2020 and Dominic Gates, "Boeing whistleblower alleges systemic problems with 737 max," *Seattle Times*, June 18, 2020, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblower-alleges-systemic-problems-with-737-max

[1014] See: Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, p.1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf and Dominic Gates, "Boeing whistleblower's complaint says 737 MAX safety upgrades were rejected over cost," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost

[1015] Boeing internal emails, "Subject: Synthetic Airspeed," February 26, 2013, p.1, accessed here: https://transportation.house.gov/imo/media/doc/Compressed%20Updated%202020.01.09%20Boeing%20Production.pdf

airspeed is standard as opposed to an option, it would likely jeopardize the Program directive to maintain Level B training for our customers.[1016]

Loss of Control

However, some Boeing engineers believed synthetic airspeed was a key feature that should have been included on the 737 MAX. A year after that email exchange, on March 3, 2014, Boeing produced an internal Coordination Sheet that provided the rationale for and description of synthetic airspeed.[1017] Synthetic airspeed was among eight proposed design changes in that document to address Boeing aircraft loss of control accidents and events on various Boeing aircraft, which included, but was not limited to, the Boeing 737 model aircraft.[1018] These Boeing aircraft events accounted for 1,493 onboard fatalities and 80 external fatalities worldwide from 2002 to 2011.[1019]

Boeing Coordination Sheet "BCA Strategy for Reducing the Risk of Loss of Control Events" March 3, 2014

"UNLIKE ALL OTHER BOEING MODELS, THE 737 HAS NO WAY TO REMOVE ERRONEOUS AIR DATA FROM A DISPLAY AND REPLACE IT WITH CORRECT DATA."

The Coordination Sheet recommended implementing synthetic airspeed on the 737 NG and the 737 MAX at the next appropriate software update.[1020] The Boeing internal document also listed three key reasons for including synthetic airspeed on the 737-model aircraft:

1) it would help to eliminate "erroneous air data" readings that can trigger an "aural" alert that "continuously sound without a way to correct or cancel" the alert;[1021]

2) erroneous airspeed can result in a stall warning speed alert that "will cause a continuous stick shaker without a way to correct the situation or cancel the alert;"[1022] and

3) "unlike all other Boeing models, the 737 has no way to remove erroneous air data from a display and replace it with correct data."[1023]

Adding synthetic airspeed would have helped to eliminate these potential conditions that could lead to pilot confusion and distraction. However, Boeing chose not to do that. A Boeing engineer involved in this issue recently wrote to the Senate Committee on Commerce, Science, and Transportation about his frustrations related to synthetic airspeed and other issues regarding the

[1016] Ibid.
[1017] Boeing Coordination Sheet, "BCA Strategy for Reducing the Risk of Loss of Control Events," B-E911-FD-13-038, March 3, 2014, BATES Number: TBC-T&I020864 – TBC-T&I020879 (On file with the Committee).
[1018] Ibid.
[1019] Ibid, at TBC-T&I020866
[1020] Ibid, at TBC-T&I020876
[1020] Ibid.
[1021] Ibid.
[1022] Ibid.
[1023] Ibid.

development of the 737 MAX. "I specifically advocated for a system that would have enabled" synthetic airspeed to be placed on the 737, "but upper management shut down the project over cost and training concerns," he wrote.[1024]

The notion of adding synthetic airspeed to the MAX was raised three separate times with Boeing managers and rejected on the basis of cost and potential pilot training impacts, according to an internal Boeing complaint filed by a Boeing engineer and reported on by both the *Seattle Times* and the *New York Times*.[1025] According to the *Seattle Times* story, Michael Teal cited those reasons when he ultimately made a decision not to include synthetic airspeed on the MAX.[1026]

According to the *Seattle Times*, the Boeing employee who filed the complaint said management was more concerned with cost and schedule than safety or quality. The complaint also alleged that Boeing hid inflight safety incident data from the European Union Aviation Safety Agency (EASA), according to the newspaper. Further, it reported that the employee who filed the complaint expressed concerns about retaliation for even raising these issues internally at Boeing. The Boeing employee apparently wrote, that given "the nature of this complaint, the fear of retaliation is high, despite all official assurances that this should not be the case. There is a suppressive cultural attitude towards criticism of corporate policy – especially if that criticism comes as a result of fatal accidents," wrote the employee.[1027]

Keith Leverkuhn, the former General Manager of the MAX program, said he was unaware of any efforts to install synthetic airspeed on the MAX until these stories appeared in the media. However, during a transcribed interview with Committee staff, he said: "[W]hat I can say is that changes to the airplane, we had a very, very detailed process associated with any change that was being forwarded to make its way on the airplane, and sometimes, those changes were not accepted and it was either due to schedule or cost, or frankly, functionality that wasn't required."[1028]

Some Boeing engineers, however, strenuously argued that synthetic airspeed was one technical feature that may have dramatically improved safety on the 737 MAX if it had been installed. Even more chilling was that the Boeing engineer who wrote to the Senate Committee on Commerce, Science, and Transportation said that in 2015 his Boeing manager argued against

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[1024] Letter from Boeing Employee to the U.S. Senate Commerce, Science, and Transportation Committee, June 5, 2020, at. p. 4. (On file with the Committee).
[1025] See: Dominic Gates, "Boeing whistleblower's complaint says 737 MAX safety upgrades were rejected over cost," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost and Natalie Kitroeff, David Gelles and Jack Nicas, "Boeing 737 Max Safety System Was Vetoed, Engineer Says," *New York Times*, (originally published) October 2, 2019, (updated October 29, 2019), accessed here: https://www.nytimes.com/2019/10/02/business/boeing-737-max-crashes.html
[1026] Dominic Gates, "Boeing whistleblower's complaint says 737 MAX safety upgrades were rejected over cost," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost
[1027] Dominic Gates, "Boeing whistleblower's complaint says 737 MAX safety upgrades were rejected over cost," *Seattle Times*, October 2, 2019, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-whistleblowers-complaint-says-737-max-safety-upgrades-were-rejected-over-cost
[1028] Committee staff transcribed interview of Keith Leverkuhn, former Boeing Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes (BCA), May 19, 2020.

including synthetic airspeed on the MAX, reportedly stating, "People have to die before Boeing will change things."[1029]

The Renton Plant Production Line

Beyond the design and development phases of the 737 MAX, schedule and production pressure were common themes on the 737 MAX on the factory floor of Renton's final assembly plant. On a January 31, 2018, fourth quarter 2017 earnings call with the media and aviation industry analysts, Dennis Muilenburg, then-Chairman, President and Chief Executive Officer (CEO) of The Boeing Company at the time discussed the Renton facility's 737 production line.[1030]

> I had a chance to be out on the line again just recently. And they're implementing productivity improvements, production line flow improvements, tack time improvements, all while rolling the MAX into the line.
>
> So while it's a challenging situation, it's a high-volume line, fast moving line. We're continuing to ramp up while we introduce the MAX into the line. It requires daily focus and daily attention. The ramp up continues on track, and we're not seeing issues or any problems that are out of the ordinary. And I remain confident that we'll achieve our MAX ramp-up goals for 2018.[1031]

Those were ambitious goals. Production of the MAX had ramped up from 42 aircraft per month to 47 aircraft per month in 2017,[1032] and Boeing set a goal of increasing the MAX production rate from 47 aircraft per month to 52 aircraft per month in 2018,[1033] with the ultimate goal of reaching a production rate of 57 aircraft per month in 2019.[1034]

For those working on the factory floor and supervising the monumental task of assembling the 737 MAX aircraft at this rapid production rate, however, the problems they encountered were intensified by the pressure to produce. In the spring and summer of 2018, with literally thousands of MAX orders on the books and production ramping up, employees at the Renton plant were working

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[1029] Letter from Boeing Employee to the U.S. Senate Commerce, Science, and Transportation Committee, June 5, 2020 (On file with the Committee).
[1030] The Boeing Company, Q4 2017 Earnings Call, January 31, 2018, p. 19, accessed here: https://s2.q4cdn.com/661678649/files/doc_transcripts/2018/Q417-Earnings-Transcript.pdf
[1031] The Boeing Company, Q4 2017 Earnings Call, January 31, 2018, p. 19, accessed here: https://s2.q4cdn.com/661678649/files/doc_transcripts/2018/Q417-Earnings-Transcript.pdf
[1032] See: The Boeing Company, Q4 2017 Earnings Call, January 31, 2018, p. 4, accessed here: https://s2.q4cdn.com/661678649/files/doc_transcripts/2018/Q417-Earnings-Transcript.pdf and Dominic Gates, "Boeing tops Airbus in 2017 with jet-production record," *Seattle Times*, January 9, 2018, accessed here: https://www.seattletimes.com/business/boeing-aerospace/boeing-tops-airbus-in-2017-with-new-jet-production-record
[1033] The Boeing Company, Q4 2017 Earnings Call, January 31, 2018, p. 19, accessed here: https://s2.q4cdn.com/661678649/files/doc_transcripts/2018/Q417-Earnings-Transcript.pdf
[1034] Ibid. The 737 MAX never met the ultimate production rate of 57 aircraft per month. The top rate of production was 52 MAX aircraft per month. See: Email from Boeing to T&I Committee staff, July 24, 2020 (On file with the Committee).

significant overtime, including back-to-back weekends.[1035] Like any large-scale industrial manufacturing facility, safety and quality control were key concerns. But the Committee's investigation has found that in at least some cases those concerns appeared to take a back seat to Boeing management's concerns about staying on schedule on the 737 MAX production line.

In particular, in June 2018, a Boeing plant supervisor at the Renton final assembly facility began to raise serious concerns with senior Boeing management regarding safety and quality control problems he was witnessing in the production of the 737 MAX.[1036] The supervisor, Edward Pierson, voluntarily retired early in August 2018 primarily due to his belief that Boeing management was not taking these issues seriously enough or confronting them thoroughly enough to adequately address his safety concerns.[1037] He had not planned to retire for several more years. However, he was uncomfortable standing by and watching these safety issues continue to percolate throughout the plant while senior Boeing management was not fully implementing his suggestions for correcting them.[1038]

Mr. Pierson was not a "disgruntled" employee or someone that habitually complained about safety problems at the Renton plant or grumbled about working conditions at Boeing. He took his job seriously and voiced his concerns about safety and quality issues at the Renton plant loudly and clearly to the senior-most official in charge of the 737 MAX production facility.[1039]

Mr. Pierson is a graduate of the U.S. Naval Academy and retired in 2015 as a Captain following 30 years of service in the U.S. Navy and U.S. Navy Reserves.[1040] Following graduation, he attended U.S. Navy Flight School in Pensacola, Florida and was designated a Naval Flight Officer. Over his career, he held various posts, including as an Action Officer for the Joint Chiefs of Staff at the Pentagon, as a Crisis Management Officer at the U.S. Department of State, as a Squadron Commanding Officer in Whidbey Island, Washington, and as Director of the Joint Operations Center at the Naval Submarine Base in Bangor, Washington.[1041] Among his assignments in the Pacific Northwest, he was selected to teach leadership and ethics to fellow Naval Officers and Non-Commissioned Officers.[1042]

In 2008, while still in the U.S. Navy Reserves, Mr. Pierson joined Boeing as part of the company's Commercial Aviation Services division and in 2010 moved to a role as Senior Manager of Business Operations in Boeing's Test & Evaluation division.[1043] From April 2015 to August 2018,

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[1035] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, pp. 74-75, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1036] Ibid, p. 75.
[1037] Ibid, pp. 74-76.
[1038] Ibid.
[1039] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p. 75, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1040] Resume of Ed Pierson, accessed here: https://docs.house.gov/meetings/PW/PW00/20191211/110296/HHRG-116-PW00-Bio-PiersonE-20191211.pdf
[1041] Ibid.
[1042] Ibid.
[1043] Ibid.

Mr. Pierson served as a Senior Manager for Production System Support for both the Boeing 737 final assembly program and Boeing's P-8 Poseidon anti-submarine warfare aircraft program.[1044] In this role, Mr. Pierson was a senior leader of the 737 MAX final assembly facility and "coordinated production for manufacturing operations with engineering, quality, tooling, supply chain, facilities and IT organizations."[1045] He also supported "team members and industrial engineers in developing production reports and metrics while leveraging data analytics to drive strategic operational improvements."[1046]

Production Pressure

In June 2018, as MAX production rates were ramping up from 47 aircraft per month to 52 aircraft per month,[1047] the problems Mr. Pierson was witnessing in the Renton plant hit a crescendo. He was concerned not just for the safety of the Boeing workforce that he managed but for the safety of the passengers who would be flying on the aircraft the Boeing factory was producing. On Saturday, June 9, 2018, at 1:32 p.m., Mr. Pierson wrote an email to Scott Campbell, the General Manager of the 737 program and the senior most official at the Renton production facility.[1048]

Ed Pierson, Boeing Senior Manager, 737 MAX Final Assembly Plant
Email to Scott Campbell, 737 General Manager
June 9, 2018

"MY FIRST CONCERN IS THAT OUR WORKFORCE IS EXHAUSTED. … MY SECOND CONCERN IS SCHEDULE PRESSURE (COMBINED WITH FATIGUE) IS CREATING A CULTURE WHERE EMPLOYEES ARE EITHER DELIBERATELY OR UNCONSCIOUSLY CIRCUMVENTING ESTABLISHED PROCESSES."

"Scott, I have some safety concerns that I need to share with you as the leader of the 737 Program," wrote Mr. Pierson.[1049] "Today we have 38 unfinished airplanes located outside the factory. The following concerns are based on my own observations and 30 years of aviation safety experience."[1050] Mr. Pierson cited two key concerns. "My first concern is that our workforce is exhausted. …. Fatigued employees make mistakes," he warned.[1051] "My second concern is schedule pressure

[1044] Ibid.
[1045] Ibid.
[1046] Ibid.
[1047] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p. 74, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1048] Email from Ed Pierson to Scott A. Campbell, The Boeing Company, "Subject: Recovery Operations & Safety Concerns," Saturday, June 9, 2018 1:32 PM, accessed here at pp. 83-84: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1049] Ibid.
[1050] Ibid.
[1051] Ibid.

(combined with fatigue) is creating a culture where employees are either deliberately or unconsciously circumventing established processes."[1052]

Ed Pierson, Boeing Senior Manager, 737 MAX Final Assembly Plant Email to Scott Campbell, 737 General Manager June 9, 2018

"FRANKLY RIGHT NOW ALL MY INTERNAL WARNING BELLS ARE GOING OFF. AND FOR THE FIRST TIME IN MY LIFE, I'M SORRY TO SAY THAT I'M HESITANT ABOUT PUTTING MY FAMILY ON A BOEING AIRPLANE.

….

I FEAR SERIOUS PROCESS BREAKDOWNS WILL CONTINUE TO OCCUR IF WE CONTINUE PUSHING OUR EMPLOYEES TO THE LIMIT."

Mr. Pierson detailed some of these specific concerns and said these issues could lead to "inadvertently imbedding safety hazard(s) into our airplanes. As a retired Naval Officer and former Squadron Commanding Officer, I know how dangerous even the smallest of defects can be to the safety of an airplane. Frankly right now," he wrote, "all my internal warning bells are going off. And for the first time in my life, I'm sorry to say that I'm hesitant about putting my family on a Boeing airplane. …. I fear serious process breakdowns will continue to occur if we continue pushing our employees to the limit," he wrote.[1053]

Mr. Pierson recommended temporarily shutting down the production line "to allow our team time to regroup so we can safely finish the planes outside and then shift our attention to the planes inside. I don't make this recommendation lightly," he wrote.[1054] "I know this would take a lot of planning, but the alternative of rushing the build is far riskier. Nothing we do is as important that it is worth hurting someone," Mr. Pierson declared.[1055]

Mr. Campbell responded to Mr. Pierson at 6:48 a.m. the following morning, Sunday, June 10, 2018.[1056] His reply suggested he clearly understood Mr. Pierson's concerns. Mr. Campbell wrote:

> We need and will remind everyone constantly that quality is number one and schedule come [sic] after that. We are trying to make sure people take time off so the [sic] can recharge…because your [sic] right we don't want people coming to work tired.[1057]

[1052] Ibid
[1053] Ibid.
[1054] Ibid.
[1055] Ibid.
[1056] Email from Scott A. Campbell, The Boeing Company, to Ed Pierson, "Subject: RE: Recovery Operations & Safety Concerns," Sunday, June 10, 2018 6:48 AM, accessed here at pp. 83-84: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1057] Ibid.

However, it took more than five weeks and another email from Mr. Pierson to Mr. Campbell's assistant to arrange a meeting on the topic.[1058] Mr. Pierson finally met with Mr. Campbell on Wednesday, July 18, 2018, in Mr. Campbell's office. Mr. Pierson described the meeting as tense.[1059] According to Mr. Pierson's testimony to the Committee in December 2019, when he walked into Mr. Campbell's office, Mr. Campbell asked him: "Why are you here?"[1060] Mr. Pierson reminded him about their email exchange and the safety issues he had raised. Mr. Pierson recalled telling Mr. Campbell: "In … military operations, if we have these kinds of indications of unstable safety type of things, we would stop."[1061] Mr. Pierson was attempting to highlight his previous recommendation that the Renton plant's production line should temporarily cease operation because of his significant safety concerns. Mr. Campbell responded: "The military is not a profit-making organization," according to Mr. Pierson.[1062]

The following day, Mr. Pierson sent an email to Mr. Campbell thanking him for his time and reiterating the concerns that he had about schedule pressure and safety issues.[1063] Mr. Campbell responded saying he was already taking actions to address these issues but did not list any specific measures he was planning to institute as a reaction to Mr. Pierson's concerns.[1064] In fact, rather than heeding Mr. Pierson's dire warnings and thoroughly evaluating his safety concerns, Boeing continued to ramp up production on the 737 MAX.[1065] Lion Air flight 610 crashed three months later.[1066]

One week after Mr. Pierson and Mr. Campbell met, Boeing held its second quarter 2018 quarterly earnings call with reporters and industry analysts.[1067] Boeing's then-CEO Dennis Muilenburg noted that production on the 737 MAX was continuing to ramp up and that the company had delivered 162 MAX aircraft to its customers to date.[1068] The Lion Air accident aircraft

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[1058] Email from Ed Pierson to Marla A. Andrus, The Boeing Company, "Subject: FW: Recovery Operations & Safety Concerns," Monday, July 9, 2018 12:47 PM, accessed here at p. 82: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1059] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 76-77: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1060] Testimony of Ed Pierson, former Boeing Employee, at Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, 116th Congress, First Session, U.S. House of Representatives, December 11, 2019, see page 139, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1061] Ibid.

[1062] Ibid.

[1063] Email from Ed Pierson to Scott A. Campbell, The Boeing Company, "Subject: FW: Recovery Operations & Safety Concerns," Tuesday, July 19, 2018 2:47 PM, accessed here at pp. 81-82: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1064] Email from Scott A. Campbell, The Boeing Company, to Ed Pierson, "Subject: RE: Recovery Operations & Safety Concerns," Thursday, July 20, 2018 6:49 AM, accessed here at p. 81: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1065] The Boeing Company, Q2 2018 Earnings Call, July 25, 2018, p. 6, p.12 and p. 26, accessed here: https://s2.q4cdn.com/661678649/files/doc_financials/quarterly/2018/q2/2Q18-Earnings-Call-Transcript-Final.pdf

[1066] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

[1067] The Boeing Company, Q2 2018 Earnings Call, July 25, 2018, accessed here: https://s2.q4cdn.com/661678649/files/doc_financials/quarterly/2018/q2/2Q18-Earnings-Call-Transcript-Final.pdf

[1068] Ibid, p. 4.

was produced shortly after that phone call. The aircraft that crashed while operating Lion Air flight 610 on October 29, 2018, was the 172nd MAX airplane to roll off the Renton factory's production line.[1069] The airplane that operated Ethiopian Airlines flight 302 was the 239th MAX aircraft to be produced.[1070]

Given the production rate at the time, it appears both planes were manufactured shortly after the time period when Mr. Pierson was raising concerns about production and safety issues at the Renton plant. In August 2018, Mr. Pierson voluntarily retired early from Boeing after one decade at the company. He believed that Boeing was more focused on the quantity of airplanes being produced rather than thoroughly correcting the quality control and safety concerns he had identified.

In September 2018, just a month after Mr. Pierson retired, several news stories reported on the disarray at the Renton plant. Things seemed to have become even worse just a few weeks after Mr. Pierson retired. The Australian magazine *Traveller* indicated that Boeing had rehired about 600 retired Boeing employees, particularly mechanics and inspectors on a temporary basis to come back to help on the production line at the Renton plant.[1071] The story indicated that the production issues that had existed at the plant in July 2018, where the factory was moving too quickly and the 737 MAX suppliers could not keep up with the plant's rapid production rate had grown even worse.[1072] According to the story, which was published on September 12, 2018, "About 50 semi-finished 737s were scattered around the Renton plant last week, analysts said, several times the number of semi-finished aircraft reported in July."[1073]

The *Seattle Times* reported that on August 30, 2018, the Renton plant was roughly 26,600 jobs behind schedule and that this number had "swelled" to about 31,000 jobs by the first week of September 2018, just one month after Mr. Pierson left his position at the plant.[1074] As the *Seattle Times* explained, "Each job is one discrete task, each varying in complexity and the time and resources for completion."[1075] These included items such as specific tests or installing electronics, for instance.

The story seemed to validate all of the issues that Mr. Pierson had laid out for Boeing's 737 General Manager Scott Campbell and had warned him about two months earlier. One worker who spoke to the *Seattle Times* described the Renton plant as being in "total chaos."[1076] Another worker said: "We're ripping apart some of the electronics racks already assembled to replace wire bundles that aren't right."[1077] The *Seattle Times* story noted that there were lots of "out-of-sequence work," which Mr. Pierson had also noted, and that some workers had worked as many as nine weekends in

[1069] Boeing email to T&I Committee Staff, April 9, 2019. (On file with the Committee).
[1070] Ibid.
[1071] "Boeing 737 MAX: Retired former employees come back to help with production," *Traveller*, September 12, 2018, accessed here: https://www.traveller.com.au/boeing-737-max-retired-former-employees-come-back-to-help-with-production-h157in#
[1072] Ibid.
[1073] Ibid.
[1074] Dominic Gates, "737 problems have grown in Renton despite Boeing's reassurances," *The Seattle Times*, September 6, 2018, accessed here: https://www.seattletimes.com/business/boeing-aerospace/737-problems-have-grown-in-renton-despite-boeings-reassurances
[1075] Ibid.
[1076] Ibid.
[1077] Ibid.

a row without a break.[1078] Others were calling in sick just to be able to take a day off and get some rest.

The *Seattle Times* also reported that some work groups at the plant had "asked their managers about perhaps stopping the production lines in order to catch up" on all of the half-finished airplanes that were accumulating at the Boeing factory. "Managers have responded categorically that a pause cannot happen because of the severe impact it would have on suppliers, on airline customers and on the company's stock price," wrote the *Seattle Times*.[1079]

No Slowing Down – Production Goes On

The Boeing 737 MAX suffered its first fatal crash in late October 2018, a little less than three months after Ed Pierson retired from Boeing on August 1, 2018 in frustration that the company was pushing production over safety. The crash of Lion Air flight 610 hit him hard. This was the concern that had caused him to worry and to warn senior Boeing officials about months earlier. While Mr. Pierson was not involved at all in the design or development of the 737 MAX and was unaware of the key design issues that have played central roles in the crash of the MAX airplanes, including the Maneuvering Characteristics Augmentation System (MCAS), which relied on a single angle of attack (AOA) sensor, he still wonders if the frantic assembly pace he witnessed and the failure of Boeing's management to quickly and fully address the safety and quality control issues he identified had inadvertently and unknowingly created a condition that may have contributed to the MAX crashes.[1080]

Following the Lion Air crash, although he was now retired, Mr. Pierson renewed his efforts to inform Boeing of the problems he had witnessed on the production line as a Boeing supervisor. On multiple occasions, he attempted to contact the lead Boeing investigator on the Lion Air accident investigation to share his experiences at the Renton factory, which he believed may have contributed to the crash.[1081] He was not successful. Finally, on December 19, 2018, he sent a letter directly to then-CEO Dennis Muilenburg.[1082]

Mr. Pierson explained who he was, his role at Boeing, and that he believed he had information about the 737 MAX production process that could be helpful for the investigation of the Lion Air crash. "I have made repeated efforts to identify and speak with the individual who is the Boeing primary lead" on the Lion Air investigation, Mr. Pierson explained to Mr. Muilenburg in

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[1078] Ibid.
[1079] Ibid.
[1080] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 74-79: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1081] Ibid.
[1082] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf and Letter from Ed Pierson to Dennis Muilenburg, CEO, The Boeing Company, December 19, 2018, accessed here at p. 85: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

his letter.[1083] He also explained that he had left his name and number with various Boeing officials several times but never received a return phone call. His letter said, in part:

> Admittedly the information I need to share isn't favorable to Boeing, but I believe it is very important nonetheless. …. Like everyone else I feel horrible for the families of the 189 people that lost their lives. My sole objective is helping to ensure this never happens again. I am specifically asking your assistance to help me get in touch with the Boeing lead.[1084]

An Assistant General Counsel for Boeing Commercial Airplanes (BCA), Padraic Fennelly, reached out to Mr. Pierson on January 7, 2019, as follow-up to Mr. Pierson's letter to Mr. Muilenburg.[1085] The two discussed Mr. Pierson's concerns.[1086]

On February 7, 2019, Mr. Pierson sent another email extensively detailing all of the production issues he had been raising to both Mr. Fennelly as well as Boeing's General Counsel, Michael Luttig.[1087] The email described the following issues that Mr. Pierson had previously raised with Boeing's management:

- Employee Fatigue & Schedule Pressure
- Leadership Actions & Inactions
- Quality Issues
- Supply Chain Disruptions
- Staffing Constraints
- Process Deviations
- Communication Breakdowns
- Safety Incidents

Ed Pierson, former Boeing Senior Manager, 737 MAX Final Assembly Plant
Email to Boeing General Counsel
February 7, 2019

"EMPLOYEES WITH 20+ YEARS 737 EXPERIENCE STATED THEY HAD NEVER SEEN THE PRODUCTION SYSTEM IN SUCH BAD SHAPE. AS YOU STATED, [BOEING] LEADERS BASED IN CHICAGO WERE AWARE OF THESE RECOVERY ISSUES.

….

THE QUESTION IS WHETHER OR NOT THERE IS THE ETHICAL LEADERSHIP AND WILL TO SET ASIDE PRIDE AND POTENTIAL LIABILITIES TO GET TO THE TRUTH."

[1083] Letter from Ed Pierson to Dennis Muilenburg, CEO, The Boeing Company, December 19, 2018, accessed here at p. 85: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1084] Ibid.
[1085] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at p. 76: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1086] Ibid.
[1087] Email from Ed Pierson to Michael Luttig, General Counsel, The Boeing Company, and Padraic Fennelly, Assistant General Counsel, Boeing Commercial Airplanes (BCA), "Subject: RE: 737 Program Safety Concerns," February 7, 2019 9:06 AM, accessed here at pp. 87-90: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

- Functional Test Delays & Failures
- Facility Limitations
- Equipment Shortcomings
- Recovery Planning Efforts
- Deteriorating Factory Health Metrics[1088]

Mr. Pierson concluded his letter to Boeing's attorneys with a warning about the risks these issues posed to Boeing, its aircraft, and the flying public:

> Taken as a whole, the sheer volume of these issues highlights the considerable & unnecessary risk the company was (is still?) taking to meet ever increasing airplane production rates and delivery schedules. Employees with 20+ years 737 experience stated they had never seen the production system in such bad shape. As you stated, leaders based in Chicago were aware of these recovery issues. Nonetheless being aware of these problems and fixing them are two completely different matters. Just because an airplane flies safely one day doesn't mean it will fly safely the next. This is the insidious nature of imbedded defects….
>
> Again to be very clear, I'm not saying anyone did anything deliberate to jeopardize the Lion Air airplane. What I am saying is production mistakes may have been made with this airplane and potentially others, due to the reasons outlined above. I believe Boeing has a duty to proactively support the accident investigation. I can't help but wonder what Boeing's response would be if this had been a U.S. airline accident. I know there are billions of dollars at stake in the contract between Boeing & Lion Air. I'm confident Boeing has the resources to fix these problems. The question is whether or not there is the ethical leadership and will to set aside pride and potential liabilities to get to the truth.[1089]

On February 19, 2019, Mr. Pierson escalated his concerns yet again, this time to Boeing's Board of Directors—all of them.[1090] He sent a detailed four-page letter that included several attachments to the dozen members of Boeing's Board of Directors. He summarized his concerns and requested that the Board look into them. He also wanted them to share his concerns with the accident investigators at the National Transportation Safety Board (NTSB), with the Federal Aviation Administration (FAA), and with Indonesian civil aviation authorities. Mr. Pierson's letter to the Boeing Board of Directors concluded:

> I have no interest in scaring the public or wasting anyone's time. I also don't want to wake up one morning and hear about another tragedy and have personal regrets. Of course, this is something no

[1088] Ibid.
[1089] Ibid., p. 89.
[1090] See: Letter from Ed Pierson to Boeing Board of Directors, February 19, 2019, accessed here at pp. 91-95: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

> one wants to happen. For what it is worth, if requested I would make myself available to the Board to answer any questions or provide additional information.
>
> I'm trying to give Boeing every opportunity to do the right thing because only Boeing can fix these internal problems. We owe it to the families devastated by the Lion Air accident, our employees, stockholders and the people that continue to trust their lives with Boeing airplanes around the world.[1091]

Mr. Pierson never received a response from the Boeing Board of Directors.[1092] Less than three weeks later the 737 MAX suffered its second fatal crash in less than five months. On March 12, 2019, two days after the Ethiopian Airlines crash, Mr. Pierson wrote to the Boeing Board of Directors again.[1093]

He reminded the Board about the previous safety issues he highlighted in his letter. "In my opinion these safety concerns came about as a result of senior leadership actions/inactions, schedule pressure, overworked employees, understaffing, process deviations, supplier and quality issues," he wrote, clearly frustrated with the Board's lack of a response to his previous letter. He continued, "I'm very proud to have worked at Boeing and truly believe these issues are all fixable. However, I'm not proud of the way Boeing has handled this matter. I have offered to help the company identify and address these issues both as an employee and as a retiree. This offer still stands," he wrote. Mr. Pierson also emphasized that his concerns about Boeing's harried production process was not limited to the 737 MAX, but also potentially impacted the 737 NG and the U.S. Navy's P-8 aircraft as well.[1094]

When Mr. Pierson wrote to the Boeing Board of Directors on February 19 and March 12, 2019, he copied all of the Board members, including David Calhoun. In December 2019, Boeing announced that Mr. Calhoun would become the company's new Chief Executive Officer (CEO) replacing Dennis Muilenburg.[1095] Mr. Pierson has said that none of the Board members, including David Calhoun, ever responded to him.

[1091] Ibid., p. 94.
[1092] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at p. 77: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1093] Letter from Ed Pierson to Boeing Board of Directors, March 12, 2019, accessed here at p. 96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1094] Ibid.
[1095] Leslie Josephs, "'He's not new blood.' What to know about Boeing's new CEO as 737 Max crisis drags on," *CNBC*, December 23, 2019, accessed here: https://www.cnbc.com/2019/12/23/what-to-know-about-new-boeing-ceo-david-calhoun.html

Renton Review

Following the Ethiopian Airlines crash on March 10, 2019, Mr. Pierson also made multiple attempts to speak with Federal agencies supporting the 737 MAX crash investigations.[1096] As part of this process, he and his attorneys sent three letters to the FAA Administrator, three letters to the NTSB, and one letter to the Secretary of Transportation Elaine Chao.[1097] He wanted them to review the production operations at Boeing's Renton production plant and to share his experience and observations with them. After this Committee initiated its investigation into the design, development, and certification of the 737 MAX and related issues, and established a whistleblower hotline,[1098] Mr. Pierson reached out to the Committee to furnish information about his experience and concerns working at the Renton final assembly facility. Mr. Pierson eventually agreed to testify publicly at the Committee's December 11, 2019, hearing on the 737 MAX.[1099]

At that hearing, both Democratic and Republican Members of Congress questioned the FAA Administrator, Stephen Dickson, about the FAA's lack of response to the concerns raised by Mr. Pierson in his multiple letters to the agency after the Ethiopian Airlines crash.[1100] Representative Sean Patrick Maloney (D-NY) was particularly alarmed and frustrated that the FAA had not responded much more thoroughly and with far greater urgency to the issues Mr. Pierson had raised.[1101] Specifically, Rep. Maloney and then-Representative Mark Meadows (R-NC) requested that the FAA take several specific actions. They requested that the FAA conduct an interview with Ed Pierson, conduct interviews of Boeing employees at the Renton 737 final assembly plant, and conduct inspections of the Renton facility, among other actions.[1102]

In a March 11, 2020, letter to Chair DeFazio, FAA Administrator Dickson provided an update on FAA's efforts to address the requests by Representatives Maloney and Meadows.[1103] According to the FAA, as of that date, the FAA had interviewed more than one dozen employees at Boeing's Renton production facility including engineers, technicians, managers, and individuals in Boeing's Organization Designation Authorization (ODA) unit; conducted a 3-hour, in-person interview of Ed Pierson; arranged for regular reporting up to Administrator Dickson of pilot

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[1096] Prepared Statement of Edward F. Pierson, former Boeing Employee, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at p. 77-78: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1097] Ibid.

[1098] "Whistleblower Rights," U.S. House Committee on Transportation and Infrastructure, accessed here: https://transportation.house.gov/whistleblower-rights

[1099] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, 116th Congress, First Session, U.S. House of Representatives, December 11, 2019, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1100] Questions from Representative Sean Patrick Maloney and Representative Mark Meadows, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 50-53: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1101] Ibid, pp. 50-53.

[1102] Ibid, pp. 50-55.

[1103] Letter from FAA Administrator Stephen Dickson to Chairman Peter DeFazio, March 11, 2020. (On file with the Committee).

complaints and disclosures through the Aviation Safety Reporting System and FAA hotline; and reviewed areas for certification improvement identified by internal reviews, including the Joint Authorities Technical Review (JATR), the NTSB, the Lion Air accident investigation report, and the Secretary of Transportation's Special Committee to Review FAA's Aircraft Certification Process.[1104]

Mr. Pierson was impressed by the FAA officials that interviewed him. However, he described the FAA's response to his concerns as "dangerously slow."[1105] It took the FAA five months to arrange an interview with him, for instance, and only after direct public pressure from Congress. He also remains highly skeptical that the agency has done enough to follow up on his concerns.[1106] Mr. Pierson provided the FAA with a list of current and former Boeing employees he believed they should interview, for instance. One of these individuals—who was at the top of Mr. Pierson's list of individuals he believed the FAA should speak with—specifically reached out to Mr. Pierson after his public testimony saying he wanted to cooperate with the FAA about his safety concerns.[1107] However, as of the end of August 2020, six months after Mr. Pierson had met with the FAA, this individual told Mr. Pierson that the FAA had still not contacted him, according to Mr. Pierson.[1108]

It should not have taken a congressional hearing, requests by multiple Members of Congress, and three letters from a former senior Boeing manager with eye-witness experience on the 737 MAX production line, for the FAA to initiate a review of the issues Mr. Pierson identified that may have affected the safety of the flying public and aviation community.

In testimony to the Committee in October 2019, Boeing's then-CEO Dennis Muilenburg, suggested that Boeing also responded to the concerns raised by Mr. Pierson.

> We took a number of actions on taking a look at each of the work locations within the factory, each of the production stops. We implemented some additional quality checkpoints in the process. We also just took a look at his concerns, because he was not actually in the factory at that point, but he raised some good concerns, so we went back and took a look at his concerns. And in some cases we identified areas where we thought his issues had already been addressed, and we provided that information back to him. But this is part of our continuous process in our factories. It is very, very important that we set up a culture where, again, safety is first in the factories.[1109]

[1104] Ibid.
[1105] Ed Pierson email to T&I Democratic Staff regarding question about his interactions with the FAA after the Committee's December 2019 hearing, July 23, 2020. (On file with the Committee).
[1106] Telephone call between Ed Pierson and his attorneys and T&I Democratic Staff, August 28, 2020.
[1107] Ed Pierson email to T&I Democratic Staff regarding question about his interactions with the FAA after the Committee's December 2019 hearing, July 23, 2020. (On file with the Committee).
[1108] Telephone call between Ed Pierson and his attorneys and T&I Democratic Staff, August 28, 2020.
[1109] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, accessed here at p. 52: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

It is apparent from Mr. Muilenburg's testimony, however, that the actions Boeing reportedly took were only taken months after Mr. Pierson raised these issues since he had already voluntarily retired from Boeing. In addition, despite Mr. Muilenburg's testimony to the contrary, Mr. Pierson says that Boeing never provided any information "back to him" regarding the issues he raised, as suggested by Mr. Muilenburg in his testimony.[1110] Furthermore, at that same hearing Chair DeFazio asked Mr. Muilenburg about the concerns Mr. Pierson raised in June and July 2018 regarding the high rate of production at the Renton plant.[1111]

> Mr. DeFazio: Did you reduce the rate of production at that point in time? ….
>
> Mr. Muilenburg: Sir, we did not change the production rate.[1112]

That response is both telling and troubling. There is no evidence that the specific production issues identified by Mr. Pierson contributed to either of the MAX crashes. However, it is very clear that Boeing did not put safety first. Boeing did not heed Mr. Pierson's advice to temporarily halt the 737 MAX's production line because it seems schedule, not safety, was Boeing's first priority.

Aside from production pressure on the factory floor, undue influence was a separate type of pressure that was experienced by many Boeing employees involved in the design, development, and certification of the 737 MAX aircraft.

Undue Influence Pressure 2016 Survey

A Boeing internal survey conducted in November 2016 at the height of the 737 MAX's certification activities, and provided to the Committee from a whistleblower, highlighted a number of findings related to undue influence at Boeing.[1113] The survey focused on Boeing's Authorized Representatives (ARs), part of the ODA program, who although they are Boeing employees, are supposed to represent the interests of the FAA.

Over 520 Boeing ODA members participated in the survey.[1114] Alarmingly, the survey found that 39 percent of the Boeing ARs that responded believed they had experienced undue pressure, painting a disturbing picture of cultural issues at Boeing that can undermine safety and oversight.[1115] In addition, of those 39 percent, 80 percent had encountered more than one situation where they perceived potential undue pressure.[1116] Boeing employees participating in the survey also provided comments identifying eight specific undue pressure related issues. Among those issues were the

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[1110] Ed Pierson email to T&I Democratic Staff regarding question about Mr. Muilenburg's testimony after the Committee's December 2019 hearing, July 22, 2020. (On file with the Committee).
[1111] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, accessed here at p. 52: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1112]Ibid, pp. 52-53.
[1113] Boeing presentation, "Undue Pressure: Key Learnings and Next Steps," The Boeing Company, November 2016, accessed here at p. 144-151: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1114] Ibid., p. 145.
[1115] Ibid.
[1116] Ibid.

following: "High Workload causes pressure," "Schedule Pressure," and the "Dual role" of ARs vs. (Boeing's) Subject Matter Experts (SMEs) that "can cause confusion leading to potential undue pressure."[1117]

At the Committee's October 30, 2019, hearing, Mr. Muilenburg emphasized that 97 percent of Boeing employees in the survey understand the "process" of reporting undue pressure, but he completely ignored the key issue he was asked about, that 39 percent of Boeing's ARs said they believed they had experienced undue pressure from Boeing employees and managers.[1118] That is a remarkable figure and should have been a warning sign to both Boeing and the FAA regarding undue pressure on Boeing employees tasked with providing critical oversight roles in the certification process.

Boeing Undue Influence Survey
November 2016

Question	% respondents Strongly Agree/Agree
I understand the process for reporting undue pressure	97
I understand what is and what is not undue pressure	93
I encounter situations where I perceive potential undue pressure	39
If yes, how frequently?	20% - once 65% - few times 11% - several times 4% - frequently
In performing my role, I have experienced undue pressure beyond my direct reporting structure	24
I am comfortable raising potential undue pressure to:	
My Management	90
SAW	92
ODA Administrators	90
I am confident the process will effectively address the issue raised	82
I am concerned about consequences if I report potential undue pressure	29
In my interactions with the FAA, I am treated fairly and professionally by the FAA	98

Testifying at the Committee's October 2019 hearing, Boeing's then-Chief Engineer, John Hamilton, said, "We do do recurrent training with managers in engineering, manufacturing and quality about how they deal with ARs, and how they need to be treated and what is undue pressure. And we do take followup actions. We do audits, and the FAA has come in and actually audited what we did, and they have agreed with what actions were taken."[1119]

Mr. Muilenburg, did, however, acknowledge that "pressure" exists but suggested that it never interferes with safety. "Now, I will say it is true that we have competitive pressures every day," admitted Mr. Muilenburg.[1120] "We operate in a tough, globally competitive world. But that never, never takes priority over safety," he said.[1121] Unfortunately, that is not what the Committee's investigation of the 737 MAX has revealed.

Despite the safety concerns raised by Mr. Pierson, the Boeing 737 MAX production line did not slow down even after the Lion Air crash. In fact, the Renton plant continued to ramp up production at the same time Mr. Pierson was raising the alarm to senior Boeing management about safety related issues. Only in April 2019, weeks after the Ethiopian Airlines crash, did production of

[1117] Ibid., p. 145.
[1118] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, accessed here at p. 102: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1119] Ibid.
[1120] Ibid., p. 52.
[1121] Ibid.

the MAX finally slow down from 52 airplanes per month to 42 airplanes per month.[1122] Production was not suspended on the MAX production line, however, until January 2020, more than 18-months after Mr. Pierson recommended this action.[1123]

In December 2019, Boeing made the announcement about the pause in production starting in early 2020. The statement said, "Safely returning the 737 MAX to service is our top priority."[1124] However, it then went on to focus on the production issues regarding the 737 MAX:

> Throughout the grounding of the 737 MAX, Boeing has continued to build new airplanes and there are now approximately 400 airplanes in storage. We have previously stated that we would continually evaluate our production plans should the MAX grounding continue longer than we expected. As a result of this ongoing evaluation, we have decided to prioritize the delivery of stored aircraft and temporarily suspend production on the 737 program beginning next month.
>
> We believe this decision is least disruptive to maintaining long-term production system and supply chain health. This decision is driven by a number of factors, including the extension of certification into 2020, the uncertainty about the timing and conditions of return to service and global training approvals, and the importance of ensuring that we can prioritize the delivery of stored aircraft. We will continue to assess our progress towards return to service milestones and make determinations about resuming production and deliveries accordingly.[1125]

Boeing did not halt production based on the safety concerns originally raised by Mr. Pierson. They did not cease production after the Lion Air crash or even after the Ethiopian Airlines crash, although production did slow down. The temporary halt in production Boeing described above had to do with schedule and delivery issues related to the MAX and not safety concerns. The 737 MAX production line restarted in May 2020.[1126]

Overall, Mr. Pierson's testimony to the Committee and the public is incredibly important. Although he clearly acknowledges that he is unaware of any specific production related safety issue that may have contributed to the Lion Air or Ethiopian Airlines crashes, his first-hand account paints a deeply troubling picture of Boeing's production first, safety second, culture among Boeing's senior leadership. He raised multiple red flags multiple times by warning Boeing's senior leaders prior to both the Lion Air and the Ethiopian Airlines crashes that Boeing's production pace and the pressure it put on its employees was endangering the safety of the public. He raised these issues with

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[1122] The Boeing Company, Q1 2019 Earnings Call, April 24, 2019, p. 4, accessed here: https://s2.q4cdn.com/661678649/files/doc_financials/quarterly/2019/q1/1Q19-Earnings-Call-Transcript-(1).pdf
[1123] Clare Duffy, "Boeing is halting production of the embattled 737 Max starting in January," *CNN*, December 17, 2019, accessed here: https://www.cnn.com/2019/12/16/business/boeing-suspends-737-max-production/index.html
[1124] "Boeing Statement Regarding 737 MAX Production," Press Release, The Boeing Company, December 16, 2019, accessed here: https://boeing.mediaroom.com/2019-12-16-Boeing-Statement-Regarding-737-MAX-Production
[1125] Ibid.
[1126] Leslie Josephs, "Boeing resumes production of beleaguered 737 Max planes," *CNBC*, May 27, 2020, accessed here: https://www.cnbc.com/2020/05/27/boeing-resumes-production-of-beleaguered-737-max.html

the General Manager of the 737 program, the Boeing General Counsel, Boeing's Chief Executive Officer (CEO) and Boeing's Board of Directors. All of them failed to respond sufficiently or swiftly enough to his warnings.

The Committee's investigation has shown that schedule pressure and cost concerns transcended the production process and greatly influenced the design and development of the 737 MAX as well. There were multiple Boeing employees who voiced concerns about the design of specific 737 MAX technologies, most notably MCAS. In other instances, safety related technologies, such as synthetic airspeed, were specifically excluded from being included on the MAX because they would have impacted cost and potentially jeopardized limited pilot training requirements. On the production side, schedule—rather than safety—seems to have been the foremost priority in the final assembly process. Taken together these issues resulted in a serious degradation to the safety of the flying public. In a rush to push forward to meet production goals and market demand for the 737 MAX, senior Boeing leaders chose to put production priorities above safety.

9. Post-Accident Response

-Post-Accident Response-

INVESTIGATIVE FINDINGS

- Both Boeing and the FAA were quick to blame the pilots of Lion Air flight 610 for the crash of that MAX aircraft and were slow to truly and fully understand and acknowledge how dangerous the design decisions and operational authority granted to the Maneuvering Characteristics Augmentation System (MCAS) was to the flight crew and safety of the airplane.[1127]

- Immediately following the Lion Air crash, both Boeing and the FAA failed to alert MAX pilots of the very existence of MCAS.[1128] The FAA even removed reference to MCAS from its draft Emergency Airworthiness Directive (AD).[1129]

- In June 2016, more than two years prior to the October 2018 crash of the Lion Air flight, Boeing engineers had predicted some of the key issues that led to the Lion Air crash, including the potential adverse consequences of erroneous AOA sensor data on MCAS, and they questioned whether or not pilots would have trouble combatting repetitive MCAS activation. These concerns, however, were either not adequately addressed or largely dismissed by their Boeing colleagues.[1130]

- Even after the Lion Air accident, Boeing balked at admitting that there were technical design issues with MCAS and that pilots of the 737 MAX needed any significant training on MCAS.[1131]

[1127] Douglas McMilan, "'Our daughter dies in van': What Boeing learns from plane crashes," Washington Post, October 28, 2019, accessed here: https://www.washingtonpost.com/business/2019/10/28/our-daughter-died-vain-what-boeing-learns-plane-crashes

[1128] See: Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled: "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 243-244: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1129] Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 241-253: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1130] See: Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOC 2]," Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC T&I 246488 – T&I 246493 at T&I 246489 (On file with Committee), and Boeing internal email, "Subject RE: Squawk for MCAS trim Event," June 20, 2016, 6:38 a.m., BATES Number TBC T&I 220826.

[1131] Draft Transcript of Audio Recording of Meeting between Boeing officials and Allied Pilots Association (APA) officials, November 27, 2018. (On file with the Committee).

INVESTIGATIVE FINDINGS - Continued

- In January 2019, in the wake of the Lion Air accident, Boeing proposed MAX pilots should only receive Level A training regarding MCAS, the lowest training level available, that encompasses simply reviewing written material.[1132]

- In December 2018, Boeing acknowledged in a presentation on MCAS to the FAA that several tests on the 737 MAX were only conducted **before** MCAS was redesigned in 2016 and not **after** it was redesigned and given increased operational authority. Still, Boeing determined that none of its missteps led to violations of FAA regulations or non-compliance.[1133]

- Similarly, in January 2019, three months after the Lion Air crash, the FAA initiated its own internal review of MCAS.[1134] This was the first detailed analysis of MCAS that the FAA conducted and the first time they were presented with a full, clear picture of how MCAS worked, according to the Department of Transportation (DOT) Office of Inspector General (OIG).[1135]

- The FAA's review resulted in a draft report that was never completed. The FAA told the IG's office that the "report was going through management review and comment at the time of the Ethiopian accident, at which time the Agency considered it overtaken by events."[1136]

- Committee staff reviewed a copy of the draft report, which found that Boeing's actions with regards to MCAS and the information they shared with the FAA during the development of MCAS was compliant with FAA regulations.[1137]

- The fact that there were so many technical misjudgments, bureaucratic missteps, and flawed design decisions surrounding MCAS, including Boeing's opaque description of MCAS to some FAA officials and its limited description to others—none of which were deemed noncompliant by the FAA—paints a deeply disturbing picture of a Federal regulatory structure in immediate need of robust reforms.

[1132] Letter from Boeing ODA Deputy Lead Administrator to FAA Aircraft Evaluation Group, January 30, 2019, BATES Number TBC-T&I 297017 - TBC-T&I 297018, accessed at pp. 134-135 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1133] "MCAS Development and Certification Overview," The Boeing Company, Presentation given by Boeing to the FAA on December 17, 2018, Bates Number TBC T&I 130073-130117, see pp. 178-201, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1134] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," DOT OIG, June 29, 2020, pp. 32-33, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[1135] Ibid.

[1136] Ibid.

[1137] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020)

Post-Accident Response

The Committee's investigation has identified many problems in the design, development, and certification of the 737 MAX aircraft. These include inadequate testing protocols on new MAX related technologies and systems,[1138] faulty assumptions on both technical design criteria[1139] and pilot reaction times,[1140] a lack of transparency on the part of Boeing with the FAA and its MAX customers,[1141] and a failure on the part of the FAA to properly fulfill its critical regulatory oversight role of Boeing.[1142]

The Committee also examined the response of both Boeing and the FAA **after** the crash of Lion Air flight 610 on October 29, 2018, and **before** the crash of Ethiopian Airlines flight 302 on March 10, 2019. The collective responses in this critical time period were woefully inadequate and appeared predisposed to blame the pilots. In the case of the FAA, even as evidence mounted that Boeing had not been fully transparent with them regarding key data and actions related to issues surrounding Boeing's analysis of the redesigned MCAS system, for instance,[1143] the agency failed to take those actions into account in regards to its decision to continue to let the 737 MAX fly.

Instead, as the months moved on and even in the aftermath of the second MAX crash of Ethiopian Airlines flight 302, the FAA appeared to follow Boeing's lead on blaming the pilots[1144] for both MAX crashes and downplaying the fundamental technical design flaws that Boeing designed

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[1138] "MCAS Development and Certification Overview," The Boeing Company, Presentation given by Boeing to the FAA on December 17, 2018, Bates Number TBC T&I 130073-130117, see pp. 178-201, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1139] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, See: Boeing internal email, AOA Sensor email string—TBC-T&I 10584–10586, December 17, 2016, accessed on p.121, here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1140] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1141] "Boeing Statement on AOA Disagree Alert," Press Statement, The Boeing Company, May 5, 2019, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130431

[1142] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1142] Ibid., p. 21.

[1143] "MCAS Development and Certification Overview," The Boeing Company, Presentation given by Boeing to the FAA on December 17, 2018, Bates Number TBC T&I 130073-130117, see pp. 178-201, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1144] See: Peter Economy, "Boeing CEO Puts Partial Blame on Pilots of Crashed 737 MAX Aircraft for Not 'Completely' Following Procedures," *Inc.,* April 30, 2019, accessed here: https://www.inc.com/peter-economy/boeing-ceo-puts-partial-blame-on-pilots-of-crashed-737-max-aircraft-for-not-completely-following-procedures.html; Curt Devine, Aaron Cooper and Drew Griffin, "Pilots union to Boeing: 'Inexcusable' to blame pilots for 737 Max crashes," *CNN*, May 23, 2019, https://www.cnn.com/2019/05/23/business/american-airlines-boeing-pilots-union/index.html; Clement Charpentreau, "Boeing 737 MAX: FAA defends its processes, blames pilots," *AeroTime*, May 16, 2019, accessed here: https://www.aerotime.aero/clement.charpentreau/22646-boeing-737-max-faa-defends-its-processes-blames-pilots; Curt Devine, "FAA chief says nothing shows agency failed in review or certification of Boeing 737 MAX," *CNN*, May 24, 2019, accessed here: https://www.cnn.com/2019/05/23/politics/faa-boeing-max-crashes-elwell/index.html

into the 737 MAX aircraft and that the FAA either did not identify or failed to adequately understand prior to its certification of the MAX.[1145]

The Pilot Response Blame Game

In the immediate aftermath of the Lion Air crash, Boeing issued a statement:

> The Boeing Company is deeply saddened by the loss of Lion Air Flight JT 610. We extend our heartfelt sympathies to the families and loved ones of those on board.[1146]

However, Boeing still shied away from taking responsibility for the design issues that clearly contributed to the fatal crash of Lion Air flight 610. Most aviation accidents are the result of multiple factors that may include pilot actions or inactions as one key component. [1147] But Boeing and the FAA overemphasized the role of the MAX pilots in the Lion Air crash and demonstrably underemphasized the technical design flaws Boeing built into the 737 MAX, particularly MCAS, that the FAA approved and that ultimately proved unsafe. Both Boeing and the FAA were slow to confront these realities even as Boeing's poor technical design choices regarding the 737 MAX and the Federal regulatory loopholes surrounding the certification of the aircraft, and particularly MCAS, came into focus and became transparent.

On November 6, 2018, eight days after the Lion Air crash, Boeing issued an Operations Manual Bulletin (OMB) that directed airline operators and flight crews to various flight crew procedures to address erroneous angle-of-attack (AOA) sensor data,[1148] which was—one week after the crash of the Lion Air flight—believed to be a core contributing cause of the accident.

The OMB issued by Boeing had the subject line, "Uncommanded Nose Down Stabilizer Trim Due to Erroneous Angle of Attack (AOA) During Manual Flight Only."[1149] The "reason" given for the bulletin was, "To emphasize the Procedures Provided in the Runaway Stabilizer Non-Normal Checklist (NNC)."[1150] The "Background Information" section of the OMB said:

> The Indonesian National Transportation Safety Committee has indicated that Lion Air flight 610 experienced erroneous AOA data. Boeing would like to call attention to an AOA failure condition that can occur **during manual flight only**. This bulletin directs flight

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[1145] Curt Devine, "FAA chief says nothing shows agency failed in review or certification of Boeing 737 MAX," *CNN*, May 24, 2019, accessed here: https://www.cnn.com/2019/05/23/politics/faa-boeing-max-crashes-elwell/index.html
[1146] "Boeing Statement on Operations Manual Bulletin," The Boeing Company, accessed here: https://boeing.mediaroom.com/news-releases-statements?item=130327
[1147] Mary S. Reveley and Jeffrey L. Briggs, et. al., "Causal Factors and Adverse Conditions of Aviation Accidents and Incidents Related to Integrated Resilient Aircraft Control," National Aeronautics and Space Administration (NASA), NASA/TM—2010-216261, November 2010, accessed here: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100040414.pdf
[1148] Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1149] Ibid.
[1150] Ibid.

> crews to existing procedures to address this condition.[1151] *(Emphasis in original).*

Noticeably absent from the Boeing bulletin was any reference to the "Maneuvering Characteristics Augmentation System" or "MCAS."[1152] It did include a description of the operational conditions associated with MCAS, though. "In the event of erroneous AOA data, the pitch trim system can trim the stabilizer nose down in increments lasting up to 10 seconds," it said.[1153] "The nose down stabilizer trim movement can be stopped and reversed with the use of the electric stabilizer trim switches but may restart 5 seconds after the electric stabilizer trim switches are released. Repetitive cycles of uncommanded nose down stabilizer continue to occur unless the stabilizer trim system is deactivated through use of both STAB TRIM CUTOUT switches in accordance with the existing procedures in the Runaway Stabilizer NNC [Non-Normal Conditions]."[1154]

The Boeing OMB also "reminded" pilots that "an erroneous AOA can cause some or all of the following indications and effects:"[1155]

- Continuous or intermittent stick shaker on the affected side only.
- Minimum speed bar (red and black) on the affected side only.
- Increasing nose down control forces.
- Inability to engage autopilot.
- Automatic disengagement of autopilot.
- IAS DISAGREE Alert.
- ALT DISAGREE Alert.
- AOA DISAGREE alert (if the AOA indicator option is installed).[1156]
- FEEL DIFF PRESS light.[1157]

The Startle Effect

The Boeing OMB did not indicate to flight crews that they may experience multiple alerts at once leading to cognitive confusion and mental overload, often referred to as the "startle effect". The FAA defines "startle" as, "An uncontrollable, automatic muscle reflex, raised heart rate, blood

[1151] Ibid.
[1152] Ibid.
[1153] Ibid
[1153] Ibid.
[1154] Ibid.
[1155] Ibid.
[1156] The AOA Disagree alert was supposed to be a standard feature on **all** 737 MAX aircraft. However, because of a software glitch the alert only worked on MAX aircraft that had also purchased an optional AOA Indicator. Boeing was aware of this issue starting in August 2017 but did not plan to implement a fix for three years until 2020 with the roll out of the MAX-10 aircraft. As a result, the AOA Disagree alert was inoperable on more than 80 percent of the 737 MAX fleet. Boeing knowingly continued to produce and deliver MAX aircraft with this known flaw and never informed the FAA and Boeing's MAX customers until after the Lion Air crash.
[1157] Ibid.

pressure, etc., elicited by exposure to a sudden, intense event that violates a pilot's expectations."[1158] This is believed to have impacted the pilots of Lion Air flight 610, impairing their ability to respond effectively to the design flaws in the 737 MAX that led to the crash.[1159]

Retired Airline Captain
Chesley B. "Sully" Sullenberger III
House Aviation Subcommittee Hearing
June 19, 2019

"WITHIN SECONDS, THESE CREWS WOULD HAVE BEEN FIGHTING FOR THEIR LIVES IN THE FIGHT OF THEIR LIVES. … IN BOTH 737 MAX ACCIDENTS, THE FAILURE OF AN AOA SENSOR QUICKLY CAUSED MULTIPLE INSTRUMENT INDICATION ANOMALIES AND COCKPIT WARNINGS."

Few pilots have survived to share their experiences about the startle effect, but retired airline captain Chesley B. "Sully" Sullenberger III is one of them. He landed U.S. Airways flight 1549 on the Hudson River in 2009 saving all 155 people on board in what came to be known as the "Miracle on the Hudson."[1160] In June 2019, Captain Sullenberger testified before a Subcommittee on Aviation hearing on the 737 MAX accidents.[1161] In his prepared statement Captain Sullenberger wrote:

> I'm one of the relatively small group of people who have experienced such a sudden crisis – and lived to share what we learned about it. I can tell you firsthand that the startle factor is real and it is huge – it interferes with one's ability to quickly analyze the crisis and take effective action. Within seconds, these crews would have been fighting for their lives in the fight of their lives.[1162]

Captain Sullenberger continued, "In both 737 MAX accidents, the failure of an AOA sensor quickly caused multiple instrument indication anomalies and cockpit warnings." He also made clear that the pilots should not be blamed for the tragic MAX crashes. "Accidents are the end result of a causal chain of events, and in the case of the Boeing 737 MAX, the chain began with decisions that had been made years before, to update a half-century-old design," he wrote.[1163] However, as we now know, and the Committee's investigation has clearly documented, one of Boeing's key goals for the

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[1158] FAA Advisory Circular, "Subject: Upset Prevention and Recovery Training," AC No: 120-111, Federal Aviation Administration (FAA), January 4, 2017, p. 3, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_120-111_CHG_1.pdf
[1159] Prepared statement of retired Captain Chesley B. "Sully" Sullenberger III, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/Sully%20Sullenberger%20Testimony.pdf
[1160] Biography of Chesley N. Sullenberger, III, U.S. House of Representatives Committee Repository, accessed here: https://docs.house.gov/meetings/PW/PW05/20190619/109642/HHRG-116-PW05-Bio-SullenbergerC-20190619.pdf
[1161] Prepared statement of retired Captain Chesley B. "Sully" Sullenberger III, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation, Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, June 19, 2019, accessed here: https://transportation.house.gov/imo/media/doc/Sully%20Sullenberger%20Testimony.pdf
[1162] Ibid.
[1163] Ibid.

737 MAX program was ensuring that pilot simulator training on the MAX was **not** required.[1164] The Boeing OMB failed to directly alert crews to the fact that the Lion Air pilots were overcome by multiple warnings and alerts leading to confusion in the cockpit. It also did not reference MCAS.[1165]

In a set of safety recommendations issued following the Lion Air and Ethiopian Airlines accidents, the U.S. National Transportation Safety Board observed that Boeing failed to account for the multitude of seemingly unrelated cautions and warnings, including an attention-getting stick shaker, when assessing that only four seconds would be needed for pilots to successfully respond to an erroneous MCAS activation.[1166] Moreover, a University of North Dakota researcher concluded in his dissertation in 2016 that pilots don't regain their full cognitive abilities for 30 to 60 seconds after a "startle" event.[1167] The conspicuous omission from the Boeing OMB of information relevant to the role of the startle factor in the Lion Air accident is consistent with Boeing's failure to establish realistic assumptions regarding the time necessary for pilots to successfully respond to an erroneous MCAS activation.

The OMB did indicate to flight crews, however, that the AOA Disagree alert, which was a standard feature on all 737 MAX aircraft and which the FAA required to be functional on every MAX aircraft Boeing delivered was only working on less than 20 percent of those aircraft where the Boeing customers had also purchased the optional AOA Indicator.[1168] But it did this in a subtle, nuanced way. As cited above, Boeing simply wrote: "AOA DISAGREE alert (if the AOA indicator option is installed)."[1169] Even in the wake of the Lion Air crash Boeing continued to obscure information related to the 737 MAX rather than being straightforward, transparent, and complete in the data they provided.

[1164] Boeing internal email, "Subject: 737MAX Firm Configuration Status/Help Needed," Saturday, May 4, 2013, BATES Number TBC T&I 049683-049684, (On file with Committee), Released at Hearing before the House Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 129, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1165] Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1166] "Safety Recommendation Report: Assumptions Used in the Safety Assessment Process and the Effects of Multiple Alerts and Indications on Pilot Performance," National Transportation Safety Board (NTSB), September 19, 2019, at p. 8, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/ASR1901.pdf

[1167] Michael Gillen, "A study evaluating if targeted training for startle effect can improve pilot reactions in handling unexpected situations in a flight simulator," Dissertation, University of North Dakota (in partial fulfillment of the requirements for the degree of Doctor of Philosophy), December 1, 2016, accessed here: https://commons.und.edu/theses/345

[1168] Boeing AOA Disagree Alert Narrative. BATES Number TBC-T&I 267826 – TBC-T&I 267833 (On file with Committee); and Alan Levin, "Boeing Failure to Fix 737 MAX Warning Light May Draw FAA Penalty," Bloomberg, February 21, 2020, accessed here: https://www.bloomberg.com/news/articles/2020-02-21/boeing-failure-to-fix-737-max-cockpit-light-may-draw-faa-penalty

[1169] Flight Crew Operations Manual Bulletin for the Boeing Company, Number TBC-19, 737-8/-9, Uncommanded Nose Down Stabilizer Trim Due To Erroneous Angle of Attack (AOA) During Manual Flight Only, November 6, 2018, accessed here at pp. 95-96: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

FAA's Emergency Airworthiness Directive

On November 7, 2018, the day after Boeing issued its OMB, the FAA issued an Emergency AD) to owners and operators of the 737 MAX.[1170] Like the Boeing OMB, the FAA's AD did not reference the "Maneuvering Characteristics Augmentation System" or "MCAS."[1171] It also did not even include any specific reference to the Lion Air crash.[1172] The FAA's Emergency AD said:

> This emergency AD was prompted by analysis performed by the manufacturer showing that if an erroneously high single angle of attack (AOA) sensor input is received by the flight control system, there is a potential for repeated nose-down trim commands of the horizontal stabilizer. This condition, if not addressed, could cause the flight crew to have difficulty controlling the airplane, and lead to excessive nose-down attitude, significant altitude loss, and possible impact with terrain.[1173]

Predicting Problems

More than two years earlier, on June 15, 2016, a Boeing Authorized Representative (AR) asked his colleagues: "What happens when we have faulty AOA or Mach number?"[1174] His colleague, a Boeing engineer, quickly assured him that this was not something to worry about. "As for faulty AOA and/or Mach number," his colleague responded, "… if they are faulty then MCAS shuts down immediately."[1175] That may have been the intent, but that did not happen on Lion Air flight 610.

The following day, on June 16, 2016, another issue that would ultimately prove critical to the Lion Air crash was also raised by a Boeing employee. A different Boeing engineer who was aware of a Boeing test pilot having trouble countering repetitive MCAS activations during a test flight asked his colleague if the difficulties the Boeing test pilot had countering repetitive MCAS activation was a safety or a certification issue. His Boeing colleague responded:

[1170] Emergency Airworthiness Directive to Owners and Operators of the Boeing Company Model 737-9 and -9 Airplanes, Federal Aviation Administration (FAA) Aviation Safety, AD #: 2018–23–51, November 7, 2018, p. 1, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf

[1171] Emergency Airworthiness Directive to Owners and Operators of the Boeing Company Model 737-9 and -9 Airplanes, Federal Aviation Administration (FAA) Aviation Safety, AD #: 2018–23–51, November 7, 2018, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf

[1172] Ibid.

[1173] Ibid.

[1174] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOC 2]," Wednesday, June 15, 2016, 1:01 PM, BATES Number TBC T&I 246488 – T&I 246493 at T&I 246489. (On file with Committee).

[1175] Boeing internal email, "Subject: RE: S&C Brief Summary: 1A001, Test 009-25 6/13/16 [BLOC 2]," Wednesday, June 15, 2016, 1:43 PM, BATES Number TBC T&I 246488 – T&I 246493 at T&I 246489. (On file with Committee).

> I don't think this is safety other then (sic) the pilot could fight the MCAS input and over time find themselves in a large mistrim.[1176]

Unfortunately, that is exactly what happened in the Lion Air crash. The pilots fought MCAS as it repeatedly activated more than 20 times before crashing as a result of faulty AOA sensor data.[1177] This was the sort of catastrophic scenario that at least some individuals within Boeing raised the alarm about years earlier. However, their concerns were essentially discarded with the presumption that they were invalid. Clearly, in hindsight they were not.

The lack of effort to thoroughly resolve those concerns were one of several preventable issues that resulted in tragedy. It is also a reminder that there were many points in the 737 MAX's development and path towards certification where more thorough evaluations and fuller reviews of questions raised by some Boeing technical experts could have resulted in life altering outcomes.

The FAA Emergency AD that was issued included a list of "potential effects and indications" of erroneous AOA input that is almost identical to the list in the Boeing OMB.[1178] Specifically, it directed flight crews to comply with Runaway Stabilizer procedures if they experienced uncommanded horizontal stabilizer trim movement combined with one of the following conditions:

- Continuous or intermittent stick shaker on the affected side only.
- Minimum speed bar (red and black) on the affected side only.
- Increasing nose down control forces.
- IAS DISAGREE alert.
- ALT DISAGREE alert.
- AOA DISAGREE alert (if the option is installed).
- FEEL DIFF PRESS light.
- Autopilot may disengage.
- Inability to engage autopilot.[1179]

Neither the FAA's AD nor Boeing's OMB mentioned MCAS, depriving MAX pilots of important information.

[1176] Boeing internal email, "Subject RE: Squawk for MCAS trim Event," June 20, 2016, 6:38 a.m., BATES Number TBC T&I 220826. (On file with the Committee).

[1177] See: "Lion Air Flight 610 Final Aircraft Accident Investigation Report," pp. 19-28, accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf and Sinead Baker, "This timeline shows exactly what happened on board the Lion Air Boeing 737 Max that crashed in less than 13 minutes, killing 189 people," *Business Insider*, October 29, 2019, accessed here: https://www.businessinsider.com/lion-air-crash-timeline-boeing-737-max-disaster-killed-189-2019-10

[1178] Emergency Airworthiness Directive to Owners and Operators of the Boeing Company Model 737-9 and -9 Airplanes, Federal Aviation Administration (FAA) Aviation Safety, AD #: 2018–23–51, November 7, 2018, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgad.nsf/0/83ec7f95f3e5bfbd8625833e0070a070/$FILE/2018-23-51_Emergency.pdf

[1179] Ibid.

Omitting MCAS

Stephen Dickson, the Administrator of the FAA, described the agency's rationale for not including reference to MCAS in its Emergency AD in response to questions for the record (QFRs) from Chair DeFazio at the Committee's December 11, 2019, hearing on the 737 MAX. Administrator Dickson claimed that at the time the FAA issued its Emergency AD the role of MCAS in the Lion Air accident was unclear.[1180] "Furthermore, the FAA's opinion at the time was that introducing a new system name that did not exist in the aircraft documentation available to pilots had the potential to cause confusion in an emergency situation," the FAA wrote in response to Chair DeFazio.[1181] This may have been the FAA's justification for not referencing MCAS in the AD, but nevertheless their actions resulted in omitting critical information about MCAS from 737 MAX pilots and airlines.

FAA Administrator Stephen Dickson Response to Questions for the Record from Committee Chair DeFazio December 19, 2019 Hearing

"[T]HE FAA'S OPINION AT THE TIME WAS THAT INTRODUCING A NEW SYSTEM NAME THAT DID NOT EXIST IN THE AIRCRAFT DOCUMENTATION AVAILABLE TO PILOTS HAD THE POTENTIAL TO CAUSE CONFUSION IN AN EMERGENCY SITUATION.

….

THE FAA THEREFORE DECIDED TO REMOVE THE MCAS REFERENCE FROM THE DRAFT AD SO THAT FLIGHT CREWS WOULD FOCUS ON RUNAWAY STABILIZER RECOGNITION INSTEAD OF ATTEMPTING TO TROUBLESHOOT MCAS."

Both Boeing and the FAA seemed more intent on justifying their previous mistakes and missteps than in fully confronting the safety issues that began to encircle and ensnarl the 737 MAX aircraft in the aftermath of the Lion Air crash. In July 2019, the *New York Times* ran an investigative story titled: "The Roots of Boeing's 737 MAX Crisis: A Regulator Relaxes Its Oversight."[1182] The story noted that the FAA's Emergency AD made no mention of MCAS. "At the last minute, an F.A.A. manager told agency engineers to remove the only mention of the system, according to internal agency documents and two people with knowledge of the matter," the *New York Times* reported.[1183]

Mr. Dickson acknowledged this in response to QFRs from Chair DeFazio from the Committee's December 11, 2019, 737 MAX hearing. Suggesting that reference to MCAS would confuse pilots, the FAA Administrator wrote: "The FAA therefore decided to remove the MCAS reference from the draft AD so that flight crews would focus on runaway stabilizer recognition

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[1180] Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 241-253: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1181] Ibid.

[1182] Natalie Kitroeff, Daid Gelles and Jack Nicas, "The Roots of Boeing's 737 MAX Crisis: A Regulator Relaxes Its Oversight," *New York Times*, July 27, 2019, accessed here: https://nyti.ms/2K0xdd7

[1183] Ibid.

instead of attempting to troubleshoot MCAS. In an emergency situation, it was more important for a crew to recognize and respond to a runaway stabilizer event than it was to troubleshoot MCAS."[1184]

Other aviation experts, however, strongly disagree with that assessment. Dr. Mica Endsley, a senior officer at the Human Factors and Ergonomics Society and a former Chief Scientist of the U.S. Air Force also testified at that same hearing.[1185] In her response to QFRs about the FAA's Emergency AD, she wrote:

> The Emergency Airworthiness Directive (AD) was clearly insufficient for preventing the second accident [of] the 737 MAX. While the AD addressed the issue of blocked AOA sensors affecting aircraft performance, it did not address the MCAS by name, nor did it explain how the MCAS used the sensor inputs to control the aircraft's pitch, leaving pilots with an insufficient mental model of MCAS in normal and abnormal situations. More importantly, it failed to mandate training on the MCAS, on correctly identifying problems with improper MCAS operations, and on proper procedure execution.
>
> The revision to the flight manual in the AD provide only a long list of potential problems that were not sufficiently diagnostic of the MCAS failure condition. The cues received by the pilots due to degraded sensors affecting MCAS were significantly different than the cues received with a runaway stabilizer trim, the procedure that Boeing and the [FAA] AD instructed pilots to use, slowing diagnosis of the problem."[1186]

The decision by both the FAA and Boeing to omit information about MCAS from communications with the public, 737 MAX customers, and MAX pilots did not last long.

Boeing Multi Operator Message (MOM)

Three days after the FAA issued its Emergency AD, Boeing issued a Multi Operator Message (MOM) on November 10, 2018, "to all 737 NG/MAX Customers, Regional Directors,

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[1184] Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 243-244: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1185] Biography of Dr. Mica R. Endsley, U.S. House of Representatives Committee Repository, accessed here: https://docs.house.gov/meetings/PW/PW00/20191211/110296/HHRG-116-PW00-Bio-EndsleyM-20191211.pdf

[1186] Questions from Hon. Peter A. DeFazio for Mica R. Endsley, Ph.D., appearing on behalf of the Human Factors and Ergonomics Society, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 263: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

Regional Managers and Boeing Field Service Bases."[1187] The message had the subject line, "Information – Multi-Modal Stall Warning and Pitch Augmentation Operation."[1188] The MOM provided a description of MCAS that had been excluded from Boeing's original OMB and the FAA's Emergency AD. However, it was also clear that Boeing only did this under intense pressure from its 737 MAX customers who wanted more information about the Lion Air crash. According to the MOM, "Boeing has received many requests for the same information from 737 fleet operators" and the MOM provided a technical description of MCAS while never specifically mentioning the Lion Air crash.[1189]

The MOM said that the "message provides technical information and operational details" related to MCAS.[1190] For example, the MOM described how MCAS is activated, the rate and magnitude of stabilizer movement, and its repetitive nature.[1191] "The [MCAS] function is commanded by the Flight Control computer using input data from sensors and other airplane systems," the MOM said. "The MCAS function becomes active when the airplane Angle of Attack exceeds a threshold based on airspeed and altitude."[1192]

For the vast majority of 737 MAX flight crews and operators, this was the first time they learned of the existence of MCAS on the 737 MAX and any details of its operation. Boeing had requested, and the FAA had approved, removal of references to MCAS from Boeing's Flight Crew Operations Manual (FCOM) in March 2016[1193] and from the FAA's Flight Standardization Board Report in January 2017.[1194] Boeing also chose not to include reference to MCAS in its OMB released just after the Lion Air crash and the FAA acknowledged to the Committee that it had drafted—and then deleted—reference to MCAS that had originally appeared in a draft of its Emergency AD.[1195]

[1187] The Boeing Company Multi Operator Message, Subject: Information – Multi-Modal Stall Warning and Pitch Augmentation Operation, MOM-MOM-18-0655-01B, November 10, 2018, accessed here at p. 290: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf
[1188] Ibid.
[1189] Ibid.
[1190] Ibid.
[1191] Ibid.
[1192] Ibid.
[1193] Forkner Email FCOM citation.Email from Mark Forkner, Chief Technical Pilot, The Boeing Company to FAA employee, Subject: "MCAS lives in both FCCs," Wednesday, March 30, 2016 (On file with Committee).
[1194] Email from Mark Forkner, Chief Technical Pilot, The Boeing Company, to FAA employee, Subject: "a few DT updates please," Tuesday, January 17, 2017 19:00:58 (On file with the Committee).
[1195] Questions from Hon. Peter A. DeFazio for Hon. Stephen M. Dickson, Administrator, Federal Aviation Administration, Hearing titled: "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here at pp. 243-244: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

Within 48 hours of releasing the MOM to Boeing's 737 MAX customers, U.S.[1196] and foreign[1197] media outlets quickly began reporting on the existence of the MCAS, its operational function and its role in the Lion Air crash. They also focused in on the fact that Boeing had left both pilots and its 737 MAX customers in the dark about MCAS. On November 12, 2018, the *Seattle Times* ran a story with the headline: "U.S. pilots flying 737 MAX weren't told about new automatic systems change linked to Lion Air crash."[1198] The next day the *Wall Street Journal* ran a story with the headline: "Boeing Withheld Information on 737 Model, According to Safety Experts and Others."[1199] The same day *Air Transport Review*, a Russian language publication's headline exclaimed: "Pilots not warned of 737MAX stall prevention system."[1200] On November 14, 2018, a headline in the German language publication *Süddeutsche Zeitung* read: "What if the on-board computer does dangerous nonsense?"[1201]

MCAS Pilot Blowback

Both the FAA and Boeing made a tremendous miscalculation and blundered their immediate response to the Lion Air tragedy by failing to fully and directly share what they knew about MCAS and its suspected role in the crash of Lion Air flight 610 immediately after the accident. Instead, they

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[1196] See: Andy Pasztor and Andrew Tangel, "Boeing Withheld Information on 737 Model, According to Safety Experts and Others," *Wall Street Journal*, November 13, 2018, accessed here: https://www.wsj.com/articles/boeing-withheld-information-on-737-model-according-to-safety-experts-and-others-1542082575 and Dominic Gates, "U.S. pilots flying 737 MAX weren't told about new automatic systems change linked to Lion Air crash," *Seattle Times*, November 12, 2018, accessed here: https://www.seattletimes.com/business/boeing-aerospace/u-s-pilots-flying-737-max-werent-told-about-new-automatic-systems-change-linked-to-lion-air-crash/; and "Gregory Polek, "Boeing Guidance on 737 Max Stall Protection System Under Fire," *Aviation International News*, November 13, 2018, accessed here: https://www.ainonline.com/aviation-news/air-transport/2018-11-13/boeing-guidance-737-max-stall-protection-system-under-fire

[1197] See: Patrick Illinger, "What if the on-board computer does dangerous nonsense?" *Süddeutsche Zeitung,* November 14, 2018, (German language publication), accessed here: https://www.sueddeutsche.de/panorama/flugzeugabsturz-in-indonesien-was-wenn-der-bordcomputer-gefaehrlichen-unsinn-treibt-1.4210624 and
"Pilots not warned of 737MAX stall prevention system," *Air Transport Review*, November 13, 2018, (Russian language publication), accessed here: http://www.ato.ru/content/pilotov-ne-predupredili-o-sisteme-predotvrashcheniya-svalivaniya-na-737max; Juho Tuomisto, "The pilots were enraged by the secret system of Boeing's new aircraft, which could destroy the aircraft in Indonesia: "This was not told in the training" - What is MCAS?" *Yle News*, November 14, 2018, (Finnish language publication), accessed here: https://yle.fi/uutiset/3-10507125

[1198] Dominic Gates, "U.S. pilots flying 737 MAX weren't told about new automatic systems change linked to Lion Air crash," *Seattle Times*, November 12, 2018, accessed here: https://www.seattletimes.com/business/boeing-aerospace/u-s-pilots-flying-737-max-werent-told-about-new-automatic-systems-change-linked-to-lion-air-crash

[1199] Andy Pasztor and Andrew Tangel, "Boeing Withheld Information on 737 Model, According to Safety Experts and Others," *Wall Street Journal*, November 13, 2018, accessed here: https://www.wsj.com/articles/boeing-withheld-information-on-737-model-according-to-safety-experts-and-others-1542082575

[1200] "Pilots not warned of 737MAX stall prevention system," *Air Transport Review*, November 13, 2018, (Russian language publication), accessed here: http://www.ato.ru/content/pilotov-ne-predupredili-o-sisteme-predotvrashcheniya-svalivaniya-na-737max

[1201] Patrick Illinger, "What if the on-board computer does dangerous nonsense?" *Süddeutsche Zeitung,* November 14, 2018, (German language publication), accessed here: https://www.sueddeutsche.de/panorama/flugzeugabsturz-in-indonesien-was-wenn-der-bordcomputer-gefaehrlichen-unsinn-treibt-1.4210624

continued a strategy of shielding the very existence of MCAS from MAX pilots that Boeing initiated and the FAA authorized years earlier. This flawed strategy, which was justified under the presumption they did not want to confuse pilots with unnecessary information, backfired once the aviation community learned about MCAS and Boeing's efforts to omit references to MCAS from 737 MAX pilots.

Boeing Official in Meeting with Allied Pilots Association November 27, 2018

"MCAS IS A CONTROL LAW … IT'S JUST A LITTLE BIT OF SOFTWARE IN THE FLIGHT CONTROL SYSTEM THAT IS DESIGNED TO CHANGE THE HANDLING CHARACTERISTICS OF THE AIRPLANE AT HIGH ANGLES OF ATTACK."

On November 27, 2018, two weeks after Boeing issued its MOM alert to its 737 MAX customers, Boeing officials sat down with representatives from the Allied Pilots Association (APA), the union that represents the 15,000 pilots that fly for American Airlines at APA's headquarters in Fort Worth, Texas.[1202] American Airlines had 24 MAX airplanes in service at the time of the Lion Air crash.[1203] The tense meeting was recorded and the transcript was provided to the media and the Committee.[1204]

According to the draft transcript of that meeting, one of the Boeing officials attempted to explain away MCAS to the American Airlines pilots:

> MCAS is a control law, which it's–it's in the flight control system. So it's just a little bit of software in the flight control system that is designed to change the handling characteristics of the airplane at high angles of attack.[1205]

The efforts by Boeing to underplay the significance of MCAS by describing it simply as a "little bit of software" that was a "control law" within the flight computer is technically accurate, but demonstrably misleading. "Control laws" are not afterthoughts or unnecessary appendages of technical systems. They play pivotal roles in the function, utility, and safety of a multitude of various technologies. "Control laws" have permitted man to land on the moon,[1206] the advancement of

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[1202] "About Us," Allied Pilots Association (APA), accessed here: https://www.alliedpilots.org/AboutUs
[1203] "Fleet Fact Sheet," American Airlines, accessed here: https://s21.q4cdn.com/616071541/files/doc_downloads/FactSheets/2020/Fleet-Facts_022020.pdf
[1204] See: Kris Van Cleave, "Audio reveals pilots confronting Boeing about new features suspected in deadly crashes," *CBS Evening News*, May 14, 2019, accessed here: https://www.cbsnews.com/news/boeing-737-max-audio-reveals-pilots-confronting-official-about-features-suspected-in-deadly-crashes-2019-05-14; Luke Kenton, "'These guys didn't even know the damn system was on the airplane — nor did anybody else': Newly surfaced audio reveals how American Airlines pilots confronted Boeing after Lion Air crash," *Daily Mail*, May 15, 2019, accessed here: https://www.dailymail.co.uk/news/article-7032007/Newly-surfaced-audio-reveals-AA-pilots-union-pilots-confronted-Boeing-Lion-Air-crash.html; and Jan Tegler, "Learning from the MAX," *Aerospace America*, July/August 2019, accessed here: https://www.aiaa.org/docs/default-source/uploadedfiles/publications/aerospace-america-july-august-2019.pdf?sfvrsn=1f307f7d_0
[1205] Draft Transcript of Audio Recording of Meeting between Boeing officials and Allied Pilots Association (APA) officials, November 27, 2018. (On file with the Committee).
[1206] David G. Hoag, "Apollo Navigation, Guidance, and Control Systems: A Progress Report," Massachusetts Institute of Technology (MIT), April 1969, accessed here: https://web.mit.edu/digitalapollo/Documents/Chapter6/hoagprogreport.pdf

unmanned aircraft applications,[1207] physicians to perform MRIs[1208] and ultrasounds[1209] on patients, and the operational control of autonomous underwater vehicles[1210] and satellites,[1211] to name a few applications.

The argument from MAX pilots was not that they needed to know about every bit of software code or all the control laws in the airplane. In the aftermath of the Lion Air tragedy, MAX pilots argued that they needed to know—and should have been told—about critical software, namely the MCAS control law, that was designed to take control of their aircraft away from them.

At the meeting with American Airline pilots, one of the Boeing officials said that despite the reports that MCAS was a "single-point failure" system, that was not true because they believed the pilots were part of the "system" and essentially served as a backup to any technical failure of MCAS.[1212] "So the [MCAS] function and trained pilot are part of the system," said one of the Boeing officials. "So rightly or wrongly, that was the design criteria, and that's how they're being certified with the – the – the system and the pilot working together," he said.[1213]

Allied Pilots Association Official in Meeting with Boeing November 27, 2018

"THESE GUYS DIDN'T EVEN KNOW THE DAMN [MCAS] SYSTEM WAS ON THE AIRPLANE – THESE GUYS DIDN'T EVEN KNOW THE DAMN SYSTEM WAS ON THE AIRPLANE. … [N]OR DID ANYBODY ELSE… THAT'S THE PROBLEM I HAVE."

The FAA appeared to agree with Boeing regarding the notion that the MAX pilots were the redundant features for MCAS and was clearly on the same page as Boeing regarding other key design decisions about MCAS and the MAX in general. In a December 2019 transcribed interview with Committee staff, for instance, Ali Bahrami, FAA's top safety official, defended the FAA's actions in the aftermath of the Lion Air crash when the agency permitted the continued operation of the 737

[1207] Najib Menti and Tarek Hamel, "Visual servoing control law with orientation limits," *Automation in Construction*, Vol. 17, Issue 1, November 2007, accessed here: https://www.sciencedirect.com/science/article/abs/pii/S0926580507000052
[1208] Aaron Becker, Ouajdi Felfoul, and Pierre E. Dupont, "Simultaneously powering and controlling many actuators with a clinical MRI scanner," 2014 IEEE/RSJ International Conference on Intelligent Robots and Systems, September 2014, accessed here: https://ieeexplore.ieee.org/abstract/document/6942831
[1209] N. Koizumi, S. Warisawa, M. Mitsuishi, and H. Hashizume, "Impedance controller for a remote ultrasound diagnostic system," Proceedings 2002 IEEE International Conference on Robotics and Automation, May 2002, accessed here: https://ieeexplore.ieee.org/abstract/document/1013432
[1210] G. Antonelli, F. Caccavale, S. Chiaverini, G. Fusco, "A novel adaptive control law for underwater vehicles," IEEE Transactions on Control Systems Technology, Vol. 11, Issue 2, March 2003, accessed here: https://ieeexplore.ieee.org/abstract/document/1186752
[1211] G.C. Walsh, R. Montgomery, and S.S. Sastry, "Orientation control of the dynamic satellite," Proceedings of 1994 American Control Conference, June 1994, accessed here: https://ieeexplore.ieee.org/abstract/document/751710 and S. Monaco and S. Stornelli, "A nonlinear attitude control law for a satellite with flexible appendages," 1985 24th IEEE Conference on Decision and Control, December 1985, accessed here: https://ieeexplore.ieee.org/abstract/document/4048597
[1212] Draft Transcript of Audio Recording of Meeting between Boeing officials and Allied Pilots Association (APA) officials, November 27, 2018. (On file with the Committee).
[1213] Ibid.

MAX while Boeing was contemplating a redesign for MCAS.[1214] In the interview with Mr. Bahrami, he also seemed unphased by many of the revelations that have deeply disturbed many aviation experts and engineers about the MAX since they were revealed in the wake of the MAX crashes. Committee staff asked Mr. Bahrami about some of these issues in the interview:

> **Committee Staff:** On a personal level, did what FAA learned after Lion Air—MCAS reliance on a single sensor, MCAS re-design, absence of a risk assessment on the MCAS re-design, non-functioning AOA disagree alert on a majority of 737 MAX planes—raise serious red flags for you?
>
> **Ali Bahrami:** No, it did not. Because the basic—the flight deck philosophy design was based on pilot intervention and action.[1215]

The message from the FAA and Boeing was that the pilots should have compensated for the MAX's flawed technical designs. During the APA meeting with Boeing, the Boeing officials acknowledged, however, that they were looking at several changes that included preventing MCAS's repetitive activation to ensure that it only fires once, for instance. Boeing anticipated a quick fix to these problems and said fixes to MCAS would be finalized "in a fairly short period of time; weeks, not – not – not a year, but a couple – maybe six weeks-ish,"[1216] a Boeing official said. He made that prediction 22 months ago.

The Boeing official also suggested that regardless of the cause of stabilizer trim runaway, whether it was due to MCAS or something else, that the procedures to correct that condition were all the same. But a frustrated APA official, referring to the Lion Air pilots said, "These guys didn't even know the damn [MCAS] system was on the airplane – These guys didn't even know the damn system was on the airplane. … [N]or did anybody else… that's the problem I have."[1217]

Despite the heated exchanges, one of the Boeing officials attempted to emphasize that safety was Boeing's number one priority.

> You've got to understand that our commitment to safety is as great as yours. It really is. And the worst thing that can ever happen is a tragedy like this, and the—and the even worse thing would be another one. So we have to do all the things we can to make sure that this never happens again, and we will, and we always do. We have that commitment to safety.[1218]

Fifteen weeks later, the 737 MAX suffered its second fatal crash.

[1214] Committee staff transcribed interview with Ali Bahrami, FAA Associate Administrator for Aviation Safety, December 5, 2019. (On file with the Committee).
[1215] Ibid.
[1216] Draft Transcript of Audio Recording of Meeting between Boeing officials and Allied Pilots Association (APA) officials, November 27, 2018. (On file with the Committee).
[1217] Ibid.
[1218] Ibid.

The APA President at the time, Captain Dan Carey, thanked the Boeing officials for their time. "You were candid and forthright, and we really appreciate that," he said. However, there were critical details about MCAS that the Boeing officials did not share at that time, and it is unclear if the Boeing officials that briefed the APA pilots were even aware of them.

In June 2019, Captain Carey testified at an Aviation Subcommittee Hearing on the MAX. He discussed the issues with MCAS that concerned the pilot community in the wake of the Lion Air and Ethiopian Airlines crashes.[1219] Captain Carey included the following in his written testimony:

> There are certain facts we know:
>
> 1. The 737 MAX was designed to provide the same aircraft feel to the pilots as the 737. This was intended to minimize the operating cost to Boeing's customers by allowing the MAX to be certified by the FAA as a 737. The point was to provide Boeing's customers with a new advanced aircraft while minimizing the training cost associated with a different aircraft certification. This led Boeing's engineers to add the MCAS system. Many mistakes were subsequently made by Boeing engineers as MCAS was designed as a "federated" not "integrated" system. As a single-point-of-failure design, this meant that any redundancy to the system, if it failed, was completely dependent on the Captain and First Officer of the aircraft.
>
> 2. The huge error of omission is that Boeing failed to disclose the existence of MCAS to the pilot community.
>
> 3. The final fatal mistake was, therefore, the absence of robust pilot training in the event that the MCAS failed.[1220]

A 10-Second "Catastrophic" MCAS Test Scenario by Boeing's Own Test Pilot

Boeing's failure to disclose the very existence of MCAS to MAX pilots was its most well-known omission, but there were others too. In the aftermath of the Lion Air crash, Boeing attempted to focus attention on the pilots as a central cause of the accident. However, they did not share the fact that one of Boeing's own test pilots in late 2012 had failed to recover from uncommanded MCAS activation that led to runaway stabilizer trim in a flight simulator.[1221] While FAA guidance indicates that pilots should recognize and react to a runaway stabilizer condition in four seconds,[1222] it took the Boeing test pilot more than 10 seconds—an amount of time that could

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[1219] Prepared Statement of Captain Daniel Carey, President, Allied Pilots Association, Hearing titled, "Status of the Boeing 737 MAX: Stakeholder Perspectives," Subcommittee on Aviation of the House Committee on Transportation and Infrastructure, 116th Congress, First Session, June 19, 2019, p. 20, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg37476/pdf/CHRG-116hhrg37476.pdf

[1220] Ibid.

[1221] Internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 2:40 PM, BATES Number TBC T&I 131226 – 131227 (On file with the Committee).

[1222] "Approval of Flight Guidance Systems," Advisory Circular (AC) 25.1329-1C, Federal Aviation Administration (FAA), U.S. Department of Transportation (DOT), October 27, 2014, at p. 78, accessed here: https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25_1329-1C_CHG_1_.pdf

have resulted in a catastrophic outcome were it to have occurred on an actual flight.[1223] This was a fundamentally important event that Boeing chose not to share with the FAA or its MAX customers.

Boeing noted the event in at least six separate internal Coordination Sheets about MCAS's requirements between 2015 and 2018, including one that was produced **after** the MAX was certified by the FAA. However, Boeing has informed the Committee that it has been unable to locate any record showing that this information was shared with the FAA.[1224] Although the Boeing test incident was noted in Boeing's internal documents, the implications of this internal test data, that should have led to increased pilot training requirements regarding how to manage MCAS, appears to have been brushed aside by Boeing and its engineers. They did not take the time to determine methods to effectively eradicate the potential for the sort of experience one of Boeing's own test pilots had in a flight simulator that the pilot found to be "catastrophic[.]" Instead, they assumed away the danger, which was a tragic miscalculation.

Surprisingly, Michael Teal, the Chief Project Engineer for the 737 MAX program, told the Committee he was not aware of this internal Boeing test data until preparing for a transcribed interview with Committee staff in May 2020. He also attempted to explain away the importance of these test results and Boeing's lack of follow-up actions saying, "I've always known that a stab trim runaway would have catastrophic effects if the pilots did not intervene."[1225]

Chair DeFazio also asked FAA Administrator Dickson in QFRs after the Committee's December 11, 2019, 737 MAX hearing whether the FAA was aware of the Boeing test pilot's 10-second response time to uncommanded MCAS activation at the time it issued its Emergency AD. Administrator Dickson's response mimicked that of Mr. Teal without directly answering the question. "At the time of [the] original 737MAX certification, the FAA knew an MCAS failure could present itself as a runaway trim stab event, which is a well-known procedure in which pilots are trained."[1226]

However, both of those responses completely miss the point. Obviously, there are potentially fatal consequences if pilots do not intervene in time to various aviation incidents or technical mishaps. In this case, however, Boeing had internal test data revealing that its own test pilot tried – but failed – to respond in time to an uncommanded MCAS activation event in a flight simulator which would have resulted in the loss of the aircraft in a real world situation. This was not simply a hypothetical scenario. It was the result of a flight simulator test by a trained Boeing test pilot. From everything the Committee has learned in its investigation, there is no evidence we have found that shows Boeing shared the results of that test with the FAA or its 737 MAX customers. Boeing simply assumed away this potentially deadly scenario with the false expectation that pilots would be the backup to any technical design flaw. Boeing gambled on the fact that the pilots would

[1223] Internal email from Boeing engineer to two Boeing test pilots, "Subject: MCAS Hazard Assessment," Sent: November 1, 2012, 2:40 PM, BATES Number TBC T&I 131226 – 131227 (On file with the Committee).
[1224] Email from Boeing attorney to T&I Committee staff, February 10, 2020, 10:42 PM (On file with the Committee).
[1225] Committee staff Transcribed Interview of Michael Teal, former Vice President, Chief Project Engineer and Deputy Program Manager for the 737 MAX program, Boeing Commercial Airplanes (BCA), May 11, 2020.
[1226] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p. 244, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

be the fail-safe mechanism to prevent an aviation tragedy which contributed to fatal consequences in both MAX crashes.

Red Flags

For the FAA, in the aftermath of the Lion Air crash, there were other warning signs that emerged regarding Boeing's testing of MCAS and the FAA's own certification review of MCAS that should have raised additional red flags about potential safety issues on the 737 MAX. On December 17, 2018, Boeing met with FAA officials to provide them with an "MCAS Development and Certification Overview."[1227] A core theme that has emerged from the Committee's investigation is that both Boeing and the FAA did identify testing lapses and other problems regarding the lack of completeness of the certification review of the 737 MAX, particularly MCAS, in the wake of the Lion Air crash, yet they both reached the conclusion that these actions were still compliant with FAA regulations.

Boeing's MCAS overview made this point absolutely clear. The presentation identified multiple missteps, yet Boeing concluded none of these resulted in any process violations or non-compliances with the FAA's regulations. For instance, Boeing concluded:

- Erroneous AOA data was "identified and not analyzed as part of" the single & multiple failure assessment "per Engineering judgment."[1228]
- The single & multiple failure assessment "analysis [was] complete prior to the design change to MCAS control law during flight test." However, "[r]eevaluation of [the] design change [was] not required…"[1229]
- The Boeing review also determined that there was "[n]o process violation or non-compliance" for the removal of the MCAS Control Law from the Flight Crew Operations Manual (FCOM) and the pilot Differences Training Table.[1230]
- There was "[n]o process violation or non-compliance" regarding "repeated unintended MCAS control law activation" because during the MAX development this was "deemed no worse than single unintended MCAS activation."[1231]
- The description of the functional failure of MCAS in the Fault Hazard Assessment table referenced the "preliminary MCAS control law authority limits and was not updated to reflect [the] certified design."[1232]

[1227] "MCAS Development and Certification Overview," Boeing presentation to FAA, December 17, 2018, TBC-T&I 130075– TBC-T&I 130117, at pp. 178-201, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1228] Ibid., p. 191.
[1229] Ibid.
[1230] Ibid., p. 197.
[1231] Ibid.
[1232] Ibid., p. 198.

- Erroneous AOA data from a single AOA sensor "was identified and not analyzed as part of" the single & multiple failure assessment. This did not entail a "process violation or non-compliance."[1233]

- Loss of one AOA sensor followed by erroneous AOA data from the second AOA sensor "was not evaluated in the simulator but deemed acceptable as failure was found to be extremely improbable." This did not entail a "process violation or non-compliance."[1234]

- The single and multiple failure analysis was "completed prior to the design change to MCAS control law during flight test and not reevaluated." This did not entail a "process violation or non-compliance."[1235]

Although the Boeing presentation highlighted many areas where a more robust review should have been conducted, it still asserted that none of these failures, either singularly or in combination with each other, amounted to a violation of FAA regulations.

In its own examination of MCAS after the Lion Air crash, in early 2019, the FAA reached the same conclusion.[1236] The FAA did not identify **any** "noncompliances" by Boeing despite the litany of incomplete test results on MCAS, the lack of transparency by Boeing with the FAA on critically important data regarding potential pilot reactions to uncommanded MCAS activation, or the disjointed communications by Boeing with the FAA regarding the redesign of MCAS. This points to a current aviation regulatory framework that demands critical and urgent reforms.

Risk Analysis: Gambling with the Public's Safety

Even after the Lion Air crash both Boeing and the FAA continued to gamble with the public's safety. The FAA often uses a quantitative method in an attempt to predict the potential for future accidents or the risk of technical incidents.[1237] This Transport Airplane Risk Assessment Methodology (TARAM) was used to evaluate the conditions that led to the Lion Air crash in order to predict the risk to the 737 MAX fleet of another potential accident.[1238]

On December 3, 2018, less than one week after Boeing's meeting with the APA pilots, the FAA prepared a quantitative risk assessment, known as a Random Transport Airplane Risk Analysis

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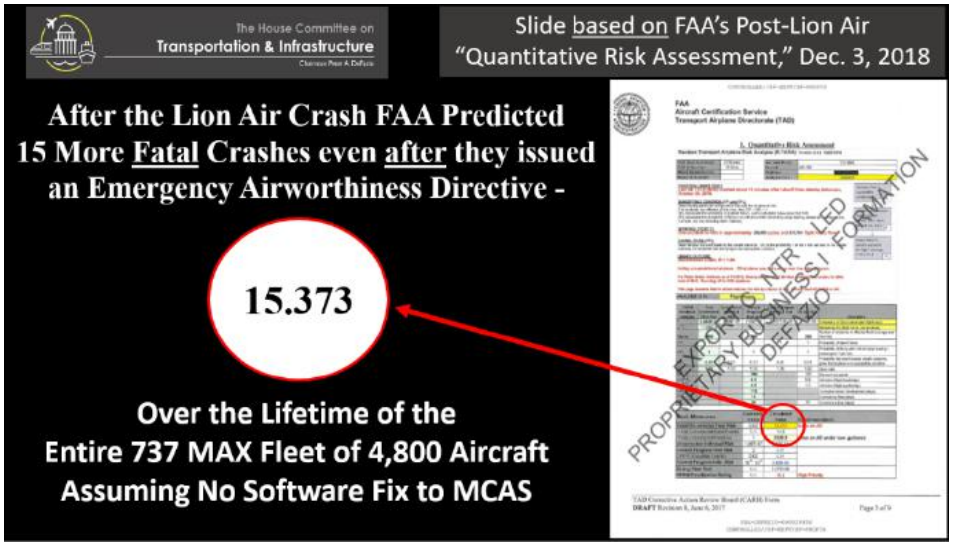
[1233] Ibid.
[1234] Ibid.
[1235] Ibid.
[1236] "FAA MCAS Oversight Report," February 8, 2019, Prepared by: FAA AIR-860 BASOO, (Draft), Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA). This document was reviewed remotely by Committee staff on May 1, 2020.
[1237] "Transport Airplane Risk Assessment Methodology (TARAM) Handbook," FAA Transport Airplane Directorate, ANM-100, accessed here: https://rgl.faa.gov/Regulatory_and_Guidance_Library/rgPolicy.nsf/0/4e5ae8707164674a8625795100 61f96b/$FILE/PS-ANM-25-05%20TARAM%20Handbook.pdf
[1238] Federal Aviation Administration, TAD Corrective Action Review Board Presentation Form, "Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high," 18-PAD-0048, December 11, 2018, BATES Number FAA-DEFAZIO-000028834 – 000028842, p. 165 -173, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

(R-TARA), that was based on the TARAM method of analysis regarding the risk to the 737 MAX fleet from continued operations.[1239] The analysis was reviewed by the FAA's Seattle Aircraft Certification Office's Corrective Action Review Board (CARB) during a presentation on December 11, 2018, titled, "Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high."[1240]

The analysis was based on the assumption that only one out of 100 pilots would fail to react properly to uncommanded MCAS activation resulting in Stabilizer Trim Runaway.[1241] This seems to be a gross over estimation that predicted 99 out of every 100 pilots would correctly respond to this scenario, given the fact that one of Boeing's own test pilots failed to respond quickly enough in a simulator test. It seems the number of potential future accidents without a fix to MCAS may have been much higher than these predictions assumed.


The House Committee on
Transportation & Infrastructure
Slide based on FAA's Post-Lion Air
"Quantitative Risk Assessment," Dec. 3, 2018
After the Lion Air Crash FAA Predicted
15 More Fatal Crashes even after they issued
an Emergency Airworthiness Directive -
15.373
Over the Lifetime of the
Entire 737 MAX Fleet of 4,800 Aircraft
Assuming No Software Fix to MCAS

Nevertheless, the results of the TARAM analysis indicated that even with the FAA's Emergency AD, but without a fix to MCAS, there could be more than 15 fatal 737 MAX crashes over the estimated 30-year lifetime of the fleet, then estimated to be 4,800 aircraft, resulting in over 2,900 deaths.[1242] Statistically this meant that the FAA was predicting there would be one fatal 737 MAX accident every two years for the next 30 years—or one fatal accident roughly every 24 months for the next 360 months. The FAA assumed that these potential future crashes would result in the loss of life for everyone on board the planes and some bystanders on the ground as well.[1243] However, they also estimated that Boeing would

[1239] Ibid., p. 167.
[1240] Federal Aviation Administration, TAD Corrective Action Review Board Presentation Form, "Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high," 18-PAD-0048, December 11, 2018, BATES Number FAA-DEFAZIO-000028834 – 000028842, p. 165 -173, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1241] FAA briefing to Committee staff, December 4, 2019.
[1242] FAA briefing to Committee staff, December 4, 2019, and Federal Aviation Administration, TAD Corrective Action Review Board Presentation Form, "Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high," 18-PAD-0048, December 11, 2018, BATES Number FAA-DEFAZIO-000028834 – 000028842, p. 167, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1243] Federal Aviation Administration, TAD Corrective Action Review Board Presentation Form, "Title: Maneuver Characteristics Augmentation System (MCAS) response to Angle of Attack (AOA) failed high," 18-PAD-0048, December 11, 2018, BATES Number FAA-DEFAZIO-000028834 – 000028842, p. 167, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf (Note: The Injury Ratio factor of 1.05 means the loss of 5 bystanders for every 100 airplane occupant losses.)

have a fix for MCAS by July 2019.[1244] Until MCAS was fixed, however, the aircraft and its passengers were still at risk.

Despite the TARAM analysis, the FAA permitted the 737 MAX aircraft to continue flying. In addition, Boeing continued to expand the MAX fleet in between the time of the Lion Air crash in October 2018 and the Ethiopian Airlines crash in March 2019.[1245] In those five months, Boeing delivered nearly 150 more aircraft to its customers, increasing the global 737 MAX fleet to 387 aircraft.[1246] Each new aircraft deployed without a fix to MCAS increased the risk to the public. The FAA and Boeing were gambling on the fact that issuance of the Boeing OMB and the FAA's Emergency AD would be enough to save MAX pilots and the flying public from the potentially devastating and deadly effect of MCAS.

Analyzing the TARAM Analysis

At the Committee's December 2019 hearing, Chair DeFazio asked FAA Administrator Dickson if he believed the MAX fleet should have been grounded given the TARAM analysis after the Lion Air crash. Administrator Dickson emphasized that the FAA is a "data-driven organization" and said there is no acceptable number of aviation accidents.[1247] "So remember," he continued, "the information that was available at the time was we really didn't know what the root cause of the accident—" was, said Administrator Dickson.[1248]

Administrator Dickson appeared to back track on his original comments in his response to QFRs from Chair DeFazio regarding the FAA's knowledge of the role of MCAS in the Lion Air crash. "After the Lion Air accident, the FAA knew there was a faulty AOA sensor which sent incorrect information to the aircraft flight control computer which then erroneously attempted to correct a nonexistent high angle of attack situation by trimming the aircraft nose down via the MCAS system," Administrator Dickson wrote in his response.[1249]

Administrator Dickson's original response at the hearing that the FAA was unaware of the "root cause" of the Lion Air accident also contradicts other information he provided in responses to QFRs regarding the FAA's preparation of the TARAM. A final analysis of the "root cause" of the Lion Air crash would take a full year to complete,[1250] but MCAS became the primary culprit of that tragedy almost immediately after the fatal Lion Air crash.

[1244] U.S. Department of Transportation, Office of Inspector General, "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Report No. AV2020037, June 29, 2020, at p. 32, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[1245] Boeing 737 MAX Deliveries Report, The Boeing Company, accessed here: http://www.boeing.com/commercial/#/orders-deliveries

[1246] Ibid.

[1247] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," House Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p.20, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1248] Ibid., p. 21.

[1249] Ibid., p. 244

[1250] "Lion Air Flight 610 Final Aircraft Accident Investigation Report," accessed here: https://aviation-is.better-than.tv/737%20MAX%202018%20-%20035%20-%20PK-LQP%20Final%20Report.pdf

Administrator Dickson's written follow-up response to Chair DeFazio's QFRs painted a different picture of what FAA knew at the time it issued its Emergency AD than what he had said in his testimony at the hearing. Administrator Dickson wrote: "The FAA issued an emergency AD reminding pilots how to deal with runaway speed trim eight days after the Lion Air accident and before the TARAM analysis was complete. When the AD was issued, the FAA determined the permanent action was to require a design change to address MCAS."[1251]

So, despite his testimony that FAA was unaware of the root cause of the Lion Air accident, it is clear that the FAA was fully aware that MCAS was a primary cause of the Lion Air accident at the time it conducted the TARAM analysis in late 2018. Despite that, the FAA chose to let the 737 MAX keep flying with the uncorrected and dangerously defective MCAS software operating on the airplanes.

TARAM Risk Analysis: Who Knew?

The FAA provided the Committee with a copy of their TARAM analysis and related presentations. However, the FAA has refused to respond to questions from Chair DeFazio about who exactly at FAA was aware of the TARAM analysis at the time it was conducted. The FAA has also refused to provide the Committee with internal FAA communications about the TARAM analysis that was requested by Chair DeFazio in follow up QFRs to Administrator Dickson. The FAA's response to these requests has been disappointing. "The FAA senior staff who prepared the TARAM were interviewed by Committee Staff," the FAA wrote in response to this request.[1252] "They answered staff questions related to the TARAM," the FAA said. That is true. It is also completely unresponsive to Chair DeFazio's specific request for information on who was aware of the TARAM analysis and not just who prepared the document.

Based on its investigation, the Committee understands that the TARAM analysis was presented to the Seattle Aircraft Certification Office's Corrective Action Review Board (CARB). However, we remain unaware of who within FAA's senior leadership was aware of the fact that the FAA had conducted an internal statistical analysis predicting that another 15 fatal MAX accidents would occur over the lifetime of the MAX fleet if there was no fix to MCAS—and then permitted the MAX to keep flying.

Despite not knowing who was aware of the TARAM, the Committee does know that the FAA's Associate Administrator for Aviation Safety, Ali Bahrami, for instance, said he was familiar with the TARAM process, but not the specific details regarding the TARAM analysis conducted after the Lion Air crash, according to his interview with Committee staff.[1253] "I'm not familiar with the details of it," he said.[1254]

This raises several disturbing questions regarding top level FAA management of critical safety issues that can have dire implications for the flying public. Although Mr. Bahrami said he was

[1251] Ibid., p. 245.
[1252] Ibid.
[1253] Committee staff transcribed interview of FAA Associate Administrator for Aviation Safety Ali Bahrami, December 5, 2019.
[1254] Ibid.

unfamiliar with the details of the TARAM analysis that predicted 15 more fatal MAX crashes over the lifetime of the MAX fleet, he said he believed FAA officials "used the [TARAM] process the right way."[1255] He also acknowledged that the Emergency AD and the focus on pilot responses was only an interim fix. "[T]he fundamental issue was the redesign of the MCAS system, which [was] going to happen via software change, which immediately started right after the first accident," said Mr. Bahrami.[1256]

In his interview with Committee staff, Mr. Bahrami was asked about the decisions to permit the 737 MAX to keep flying passengers while awaiting a fix for MCAS.

> **Committee staff:** But you made a decision that those changes could wait --
>
> **Ali Bahrami:** Yes, we did.
>
> **Committee staff:** -- and still the plane could fly, and you were relying on the pilots to prevent a catastrophic failure.
>
> **Ali Bahrami:** There are a lot of other scenarios out there that we -- again, it gets back to the cockpit design philosophy. Pilots are part of the system, and we rely on the pilots to do certain things.[1257]

Mr. Bahrami briefed Chair DeFazio and Subcommittee on Aviation Chair Larsen on the Lion Air accident on February 14, 2019.[1258] Even though there was plenty of evidence mounting within the FAA regarding the fatal MCAS flaws in the 737 MAX at that time, Mr. Bahrami and the others from the FAA at that time continued to focus their time on blaming the Lion Air pilots. It seemed they were thoroughly convinced that MCAS was an easy fix and that the pilots deserved the vast bulk of the blame for the accidents. At that time the FAA and Mr. Bahrami described the Lion Air accident as a "one-off" to Chairs DeFazio and Larsen.[1259] Less than one month later Ethiopian Airlines flight 302 became the second MAX aircraft to crash in less than five months killing all on board.

Mr. Bahrami first began work for the FAA in 1989 and later served as the Manager of the FAA's Transport Airplane Directorate in Renton, Washington from 2004 to 2013.[1260] He left FAA in the wake of Boeing's last grounding of the 787 Dreamliner that suffered two lithium battery fires

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[1255] Ibid.
[1256] Ibid.
[1257] Ibid.
[1258] Ali Bahrami, Associate Administrator for Aviation Safety, Federal Aviation Administration (FAA), briefing to Chair DeFazio and Subcommittee Chair Larsen, February 14, 2019.
[1259] See comments by Chair DeFazio, Hearing titled: "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p. 19, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf
[1260] Ali Bahrami, Associate Administrator for Aviation Safety, Federal Aviation Administration (FAA), Biography, accessed here: https://www.faa.gov/about/key_officials/bahrami_avs/

on the aircraft.[1261] A subsequent investigation by the National Transportation Safety Board (NTSB), that was completed in November 2014, identified several issues regarding Boeing and the FAA that draw striking parallels to problems identified in the certification of the 737 MAX today, including inadequate testing, lax oversight of Boeing by the FAA, and flawed technical assumptions.[1262]

Mr. Bahrami had served for 10 years as a senior engineer at McDonnell Douglas from 1979 to 1989, prior to joining the FAA.[1263] McDonnell Douglas merged with The Boeing Company in 1997, while Mr. Bahrami was at the FAA.[1264] In 2013, Mr. Bahrami left the FAA to take a position as the Vice President for Civil Aviation at the Aerospace Industries Association (AIA), the aviation trade group that represents Boeing and many other aviation companies.[1265] Boeing officials serve in leadership positions on AIA's Executive Committee.[1266]

Importantly, Mr. Bahrami was **not** at the FAA during the bulk of the 737 MAX's certification process and played no role in the ultimate certification of the airplane. He returned to the FAA from AIA in July 2017,[1267] four months after the 737 MAX received its FAA certification.

However, Mr. Bahrami returned to FAA as the lead safety officer in the agency. Given that role and the somber and significant consequences of the Lion Air crash, it was surprising to the Committee that Mr. Bahrami appeared to be largely disengaged from the aftermath and repercussions of the Lion Air accident. He was unaware of the FAA's TARAM analysis. He also said he was unaware that Boeing had internal test data showing that it took of Boeing's own test pilots more than 10-seconds to respond to uncommanded MCAS activation, which the pilot described as "catastrophic."[1268] This was despite the fact the Committee held a hearing in October 2019 where this information was released and it was widely covered by the media.[1269] In addition, and perhaps most surprisingly, Mr. Bahrami claimed to not recall **any** conversations with **any** Boeing officials about the MAX in between the Lion Air and Ethiopian Airlines accidents.

[1261] Alwyn Scott and Andrea Shalal-Esa, "US safety board seeks lesson in Boeing 787 battery fire," *Reuters*, April 23, 2013, accessed here: https://www.reuters.com/article/us-ntsb-boeing-hearing/us-safety-board-seeks-lesson-in-boeing-787-battery-fire-idUSBRE93M0QJ20130423

[1262] "Aviation Incident Report: Auxiliary Power Unit Battery Fire Japan Airlines Boeing 787-8, JA829J, Boston Massachusetts," January 7, 2013, NTSB/AIR-14/01, National Transportation Safety Board (NTSB), November 21, 2014, accessed here: https://www.ntsb.gov/investigations/AccidentReports/Reports/AIR1401.pdf

[1263] Ibid.

[1264] Natasha Frost, "The 1997 merger that paved the way for the Boeing 737 Max crisis," *Yahoo! Finance*, January 3, 2020, accessed here: https://finance.yahoo.com/news/1997-merger-paved-way-boeing-090042193.html

[1265] "Bahrami Named Vice President of Civil Aviation," July 9, 2013, accessed here: https://www.aia-aerospace.org/news/bahrami-named-vice-president-of-civil-aviation

[1266] "Executive Committee Leadership," Aerospace Industries Association (AIA), accessed here: https://www.aia-aerospace.org/about-aia/leadership-and-governance/executive-committee

[1267] Committee staff transcribed interview of FAA Associate Administrator for Aviation Safety Ali Bahrami, December 5, 2019.

[1268] Ibid.

[1269] See: Hearing titled: "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 22, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf and Ian Duncan, Michael Laris and Lori Aratani, "House committee confronts Boeing CEO with new documents on 737 Max safety," *The Washington Post*, October 30, 2019, accessed here: https://www.washingtonpost.com/local/trafficandcommuting/house-committee-confronts-boeing-ceo-with-new-documents-on-737-max-safety/2019/10/30/ef3a8334-fa92-11e9-ac8c-8eced29ca6ef_story.html

> **Committee Staff:** Between Lion Air and the Ethiopian accident, did you have discussions with Boeing, direct discussions?
>
> **Mr. Bahrami:** I really don't recall, honestly, because I relied on the team to do -- to do their work. Most of the information, even if I have a conversation, it would be through the director, through the other people. Those are the guys that know the details.
>
> **Committee Staff:** So they would report up?
>
> **Mr. Bahrami:** Yes, they would report up to me. I don't necessarily have the specific discussion about the accident with them.
>
> **Committee Staff:** So –
>
> **Mr. Bahrami:** From Boeing.
>
> **Committee Staff:** So from what you recall, you know, you never had discussions between Lion Air and Ethiopian Air with Boeing about the MAX?
>
> **Mr. Bahrami:** I don't recall a conversation about that between the two accidents.[1270]

Chair DeFazio asked FAA Administrator Dickson about Mr. Bahrami's discussions with Boeing related to the MAX accidents in between the Lion Air and Ethiopian Airlines crashes in QFRs after the Committee's December 2019 hearing. The FAA responded:

> The Associate Administrator for Aviation Safety communicates regularly with Boeing representatives on a variety of aviation safety topics via different modes of communication, including during the time period referenced. The Associate Administrator for Aviation Safety provided more detailed information about his communications with Boeing during his transcribed interview with Committee staff on December 5, 2019.[1271]

That response is surprising since it appears to contradict what Mr. Bahrami relayed to Committee staff regarding his interactions with Boeing. While the FAA claimed that as Associate Administrator for Aviation Safety at the FAA that Mr. Bahrami frequently communicated with Boeing about safety issues, Mr. Bahrami suggested he rarely, if ever, had those direct conversations. Furthermore, Mr. Bahrami claimed not to recall having **any** discussions at all with Boeing about the MAX in between the two MAX crashes.

[1270] Committee staff transcribed interview of FAA Associate Administrator for Aviation Safety Ali Bahrami, December 5, 2019.

[1271] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p. 245, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

Despite Mr. Bahrami's lack of recollection, some of the email records the Committee received from Boeing included an email from Elizabeth ("Beth") Pasztor to Mr. Bahrami on January 24, 2019.[1272] Ms. Pasztor was the Boeing Commercial Airplane's (BCA's) Vice President of Safety, Security and Compliance.[1273] In her email to Mr. Bahrami, she wrote:

> I would appreciate a few minutes of your time, the topic is on Lion Air. Would it be possible to connect today or tomorrow? Please let me know, thanks for your time.[1274]

Mr. Bahrami responded: "Let's plan for tomorrow. Let me know what works fo[r] you." The two scheduled a call for 11:30 a.m. on January 25, 2019.[1275]

It is unclear if they actually ended up speaking to each other or who else may have been on that call. However, five days after they were scheduled to speak, Ms. Pasztor's deputy at Boeing wrote to the FAA regarding proposed pilot training requirements related to MCAS in the aftermath of the Lion Air crash.[1276] That letter was responding to a December 13, 2018, letter from the Chair of the FAA's 737 MAX Flight Standardization Board (FSB) in the agency's Seattle Aircraft Evaluation Group (AEG).[1277] The letter said that Boeing and the FAA had met the same day (on December 13, 2018) "to discuss a plan to review, evaluate, and validate B-737 MAX system enhancements to the Maneuver Characteristics Augmentation System (MCAS),"[1278] and informed Boeing that the FAA required Boeing to propose pilot training for the new MCAS enhancements.[1279]

Boeing sent a response letter on January 30, 2019, outlining Boeing's proposed training requirements for MCAS, which seemed out of touch with what was being learned about the737 MAX in the wake of the Lion Air crash.

> As you will recall, the Maneuver Characteristics Augmentation System (MCAS) flight control law was not originally included in the 737 NG to 737 MAX differences tables nor was a specific reference included in the FCOM/QRH.[1280] Boeing believes that the rationale supporting that decision remains valid.[1281]

[1272] Email from Vice President, Safety, Security and Compliance, Boeing Commercial Airplanes (BCA) to Associate Administrator for Aviation Safety, Federal Aviation Administration (FAA), January 24, 2019, 3:48 PM, BATES Number TBC T&I 552822 (On file with the Committee).
[1273] Ibid.
[1274] Ibid.
[1275] Ibid.
[1276] Letter from Boeing ODA Deputy Lead Administrator to FAA Aircraft Evaluation Group, January 30, 2019, BATES Number TBC-T&I 297017 - TBC-T&I 297018, accessed at pp. 134-135 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1277] Letter from FAA B-737 FSB Chair to Boeing, December 13, 2018, BATES Number TBC-T&I 297016, accessed here, at p. 133: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1278] Ibid.
[1279] Ibid.
[1280] FCOM/QRH stands for Flight Crew Operations Manual/Quick Reference Handbook.
[1281] Letter from Boeing ODA Deputy Lead Administrator to FAA Aircraft Evaluation Group, January 30, 2019, BATES Number TBC-T&I 297017 - TBC-T&I 297018, accessed at pp. 134-135 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

Boeing only seemed to concede that some training may be necessary simply to placate inquiries from MAX "operators" and "customers." Boeing proposed Level A training requirements on MCAS for pilots transitioning from the 737 NG to the 737 MAX.[1282] This is the least aggressive form of training available and only requires a review of written material. It was clear that by January 2019, even as Boeing was in the midst of redesigning MCAS to enhance its safety functions, the company's officials strained to admit that MCAS posed any risk at all to MAX pilots or that they needed any significant training on MCAS whatsoever. The letter continued:

> As background to support this recommendation, Boeing believes that difference between the 737 NG and 737 MAX relating to the MCAS flight control law do not affect pilot knowledge, skills, abilities, or flight safety.[1283]

Two days later, on March 1, 2019, Boeing received its response from the FAA's FSB Chair. The FAA accepted Boeing's proposal for Level A MCAS training that included conducting tests in the 737 NG and 737 MAX Full Flight Simulators on March 13, 2019, at Boeing's Miami, Florida training facility.[1284]

However, the FSB Chair reminded Boeing that when MCAS was originally described to the Seattle AEG, that it "was presented as autonomous to the pilot, operation was 'way' outside the normal operating envelope, and no flight crew procedures or checklists were affected by the addition of the flight control law. The original level of training differences that was proposed in 2016 was Level B differences," the FSB Chair wrote.[1285] The FSB Chair added,

> The FAA is concerned that software change, FCC 12.1 may not meet the definition of Level A differences. Specifically, Level A states that the change does not adversely affect safety of flight if the information regarding MCAS operation is not reviewed or forgotten. The FAA is willing to evaluate Boeing's proposal for Level A training; however, we are advising the Boeing Company that the evaluation is proceeding at risk.[1286]

Nine days later, Ethiopian Airlines flight 302 crashed six minutes after takeoff.

[1282] Ibid.
[1283] Ibid.
[1284] Letter from FAA B-737 MAX FSB Chair to Boeing 737 Chief Technical Pilot, March 1, 2019, BATES Number TBC-T&I 297019 - TBC-T&I 297020, accessed at pp. 136-137 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf
[1285] Ibid.
[1286] Ibid.

The BASOO's Post-Lion Air MCAS System Oversight Report

The FAA had begun a review of MCAS prior to the Ethiopian Airlines crash. In January 2019, the FAA's Boeing Aviation Safety Oversight Office (BASOO), based in Seattle, began compiling an after action review, "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," to look back at Boeing's submissions to FAA on MCAS as well as the office's certification work on that system.[1287] The Committee found the results of this review troubling. The FAA's draft review of MCAS following the Lion Air crash found it to be fully compliant with FAA regulations. If MCAS was compliant, yet it made the 737 MAX unsafe, this points to fundamental problems in the FAA's certification process.

The draft document concluded: "The [FAA's] oversight activity did not reveal any noncompliance [by Boeing], but did observe some assumptions used by the Applicant and accepted by the FAA. The following opportunities do not require corrective action; however, they are included to be addressed for improvement."[1288]

"737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report"
FAA's Boeing Aviation Safety Oversight Office (BASOO)
February 8, 2019

"THE [FAA'S] OVERSIGHT ACTIVITY DID NOT REVEAL ANY NONCOMPLIANCE [BY BOEING], BUT DID OBSERVE SOME ASSUMPTIONS USED BY THE APPLICANT AND ACCEPTED BY THE FAA. THE FOLLOWING OPPORTUNITIES DO NOT REQUIRE CORRECTIVE ACTION; HOWEVER, THEY ARE INCLUDED TO BE ADDRESSED FOR IMPROVEMENT."

After the Committee was informed about this document in January 2020, the Committee made numerous requests for a copy of it with both DOT and directly to FAA Administrator Dickson. The FAA refused to provide a copy of this report to the Committee because it was a draft. However, FAA did make a copy available for Committee staff to review "in camera" remotely. Committee staff reviewed the document on May 2, 2020.

According to the FAA, the document was never ultimately completed. They have claimed that their review of MCAS was going through management review and was overtaken by the crash of Ethiopian Airlines flight 302.[1289] Based on the Committee's review of the metadata associated with the draft "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report" that Committee staff reviewed, the draft document was prepared on February 8, 2019. On March 11, 2019—the day after the Ethiopian Airlines crash—the draft document was opened and printed by an FAA employee. However, the report was never finalized or officially issued.

[1287] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020).
[1288] Ibid.
[1289] "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," DOT OIG, June 29, 2020, pp. 32-33, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

According to the draft report, in multiple instances there were "traceability" issues with the documentation Boeing provided to the FAA regarding MCAS. "Not all compliance showing/findings were contained within artifacts proposed by the relevant certification plans," the draft report said.[1290] "Although Boeing was able to provide artifacts (e.g. emails and internal coordination sheets) substantiating detailed aspects of their compliance showing, not all of these artifacts were traceable via a review of the certification plans [and] our compliance deliverables." [1291] The draft concluded that while there were some assumptions made by Boeing and accepted by the FAA that there was room for improvement in the certification process.[1292]

Based on the FAA's limited original review of MCAS demonstrated by this document, as well as what has been documented elsewhere with regard to Boeing's efforts to downplay MCAS to regulators, this underscores questions about the effectiveness of the FAA's certification process. If Boeing was technically compliant, but the FAA did not have a full understanding of MCAS,[1293] and the result was two deadly plane crashes, the aviation certification process is in desperate need of repair.

Grounding the 737 MAX

The crash of Ethiopian Airlines flight 302 occurred on Sunday, March 10, 2019. The FAA, which has always prided itself on being a "data driven" organization, did not believe they had enough data—factual evidence—immediately after the Ethiopian Airlines crash suggesting that the 737 MAX was unsafe to fly. They held fast as other foreign civil aviation authorities used their authority to ground the aircraft. The FAA did not.

On March 11, 2019, the day after the Ethiopian Airlines crash, the FAA issued a Continued Airworthiness Certification to the International Community permitting the 737 MAX to keep flying. In part, the document said: "External reports are drawing similarities between this accident and the Lion Air Flight 610 accident on October 29, 2018. However, this investigation has just begun and to date we have not been provided data to draw any conclusions or take any actions."[1294]

[1290] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019, p. 8, 12 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020).
[1290] Ibid.
[1291] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019, p. 8, 12 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020); "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," DOT OIG, June 29, 2020, pp. 32-33, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf
[1292] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019, p. 8, 12 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020).
[1293] See JATR p. 13: "The FAA was not completely unaware of MCAS; however, because the information and discussions about MCAS were so fragmented and were delivered to disconnected groups within the process, it was difficult to recognize the impacts and implications of this system." accessed here: https://www.faa.gov/news/media/attachments/Final_JATR_Submittal_to_FAA_Oct_2019.pdf
[1294] FAA Continued Airworthiness Notification to the International Community, March 11, 2019, accessed here: https://www.faa.gov/news/updates/media/CAN_2019_03.pdf

By March 12, 2019, two days after Ethiopian Airlines flight 302 crashed, civil aviation authorities in China, Australia, Britain, France, Germany, Ireland, Malaysia, Mongolia, Oman and Singapore had already grounded the 737 MAX in addition to airlines in Brazil, South Africa, South Korea, Norway, India, Turkey and other countries.[1295] At the time of the Ethiopian Airlines accident the 737 MAX fleet consisted of 387 airplanes operating with 59 total air carriers worldwide, including 74 operating with U.S. based airlines.[1296]

By the evening of March 12, 2019, at 6:10 p.m. then-Acting FAA Administrator Dan K. Elwell issued a statement on Boeing's 737 MAX:

> The FAA continues to review extensively all available data and aggregate safety performance from operators and pilots of the Boeing 737 MAX. Thus far, our review shows no systemic performance issues and provides no basis to order grounding the aircraft. Nor have other civil aviation authorities provided data to us that would warrant action. In the course of our urgent review of data on the Ethiopian Airlines Flight 302 crash, if any issues affecting the continued airworthiness of the aircraft are identified, the FAA will take immediate and appropriate action.[1297]

In his transcribed interview with Committee staff, Ali Bahrami, FAA's head of safety, also said that the FAA felt they simply did not have enough data at that point to ground the MAX. However, on the morning of Wednesday, March 13, 2019, he said there was an "urgent call with Boeing" that he was asked to be on with Beth Pasztor, who had emailed him at the end of January 2019 to talk about Lion Air, in addition to the Boeing accident investigator who was on site in Ethiopia and several other people.[1298]

According to Mr. Bahrami, "Beth basically said, Ali, we have some information that we need to share with you…."[1299] Mr. Bahrami did not recall who was in the room with him, but Boeing sent them data that they put on a screen. They superimposed the traces from both the Lion Air flight and the Ethiopian Airlines flight on the screen and Boeing explained their similarities. They did not yet have the flight data recorder from the Ethiopian Airlines flight. Boeing also told Mr. Bahrami that they found physical evidence at the crash site. "The physical evidence they found was the flap actuator," said Mr. Bahrami.[1300] "[The f]lap actuator was in a retract position. And MCAS gets activated when flaps are up," said Mr. Bahrami.[1301] "So now we have data that says … the two

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[1295] "Boeing's 737 MAX 8: who's grounding, who's still flying troubled jet after Ethiopia crash," *South China Morning Post*, March 12, 2019, accessed here: https://www.scmp.com/news/world/united-states-canada/article/3001206/boeings-737-max-8-whos-grounding-whos-still-flying

[1296] FAA Continued Airworthiness Notification to the International Community, March 11, 2019, accessed here: https://www.faa.gov/news/updates/media/CAN_2019_03.pdf

[1297] March 12, 2019 6:10pm Update, Statement from FAA Acting Administrator Daniel K. Elwell https://www.faa.gov/news/updates/?newsId=93206

[1298] Committee staff Transcribed Interview of FAA Associate Administrator for Aviation Safety Ali Bahrami, December 5, 2019.

[1299] Ibid.

[1300] Ibid.

[1301] Ibid.

scenarios, maneuvers, were the same and we also have a flap actuator that is in a retract position," he said.[1302]

> I saw that and I said, thank you, anything else? And they said, well, what are you going to do? I said, we'll get back to you. And I walk out of my office, went to Dan's [Dan Elwell, then-Acting FAA Administrator's] office, and I said, we need to ground the fleet.[1303]

At 3:00 p.m. on March 13, 2019, the FAA grounded the 737 MAX fleet.[1304] The FAA issued a brief statement that said:

> The FAA is ordering the temporary grounding of Boeing 737 MAX aircraft operated by U.S. airlines or in U.S. territory. The agency made this decision as a result of the data gathering process and new evidence collected at the site and analyzed today. This evidence, together with newly refined satellite data available to FAA this morning, led to this decision.[1305]

That "temporary grounding" remains in effect as of the writing of this report. Eighteen months since the grounding went into effect the public has learned a lot more about the design decisions and certification weaknesses that led to the MAX tragedies. Multiple new problems, seemingly unrelated to the two fatal MAX crashes, have also surfaced.

[1302] Ibid.
[1303] Ibid.
[1304] "Statement from the FAA on Ethiopian Airlines," March 13, 2019 3:00 pm Update, Federal Aviation Administration (FAA), accessed here: https://www.faa.gov/news/updates/?newsId=93206; FAA Emergency Order of Prohibition to Operators of Boeing Company Model 737-8 and Boeing Company Model 737-9 Airplanes, March 13, 2019, accessed here: https://www.faa.gov/news/updates/media/Emergency_Order.pdf
[1305] "Statement from the FAA on Ethiopian Airlines," March 13, 2019 3:00 pm Update, Federal Aviation Administration (FAA), accessed here: https://www.faa.gov/news/updates/?newsId=93206

10. New Issues Emerge

-New Issues Emerge-

The 737 MAX has been grounded for 18 months following the crash of Ethiopian Airlines flight 302. During this time, Boeing has faced challenges in correcting both known problems with the airplane that contributed to both MAX crashes as well as newly identified manufacturing defects. The myriad issues that have become manifest during the airplane's grounding underscore the FAA's systemic oversight shortcomings and problems with Boeing's design, development, and production as described in this report. The combination of these weaknesses contributed to the 737 MAX's significant safety deficiencies and ultimately the crash of both MAX airplanes. The new issues that have emerged since the MAX's grounding pose additional barriers to the airplane's safe return to service.

New Issues

From software glitches to manufacturing defects and production quality deficiencies, several areas of concern related to both previously identified and newly found problems have emerged following the 737 MAX's grounding in March 2019. These include:

Nonconforming Slat Tracks

In December 2019 and January 2020, the FAA proposed $9.3 million in civil penalties against Boeing for the company's alleged installation of slat tracks—components used to guide the movement of panels (slats) on the wing's leading edge that extend to provide additional lift during takeoff and landing—that were weakened during the manufacturing process.[1306] These proposed penalties cover 133 Boeing 737 NG airplanes and 178 Boeing 737 MAX airplanes. The FAA says that Boeing's failure to oversee its suppliers resulted in the installation of slat tracks that were weakened by a condition known as hydrogen embrittlement that occurred during cadmium-titanium plating.[1307] The FAA had previously issued an Airworthiness Directive (AD) in June 2019 to require inspections of affected aircraft and various actions based on the ability to identify the faulty slat tracks.[1308]

Flight Control Computer

In January 2020, the two flight control computers installed on a 737 MAX test airplane failed to properly power-up after the installation of updated software that Boeing developed following the Lion Air and Ethiopian Airlines crashes.[1309] The software intended to monitor the power-up

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[1306] FAA Press Release, "FAA Proposes $3.9 Million Civil Penalty Against The Boeing Co.," December 6, 2019, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24456 and FAA Press Release, "FAA Proposes $5.4 Million Civil Penalty Against The Boeing Co.," January 10, 2020, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24574

[1307] Ibid.

[1308] Identification of the defective slat tracks was hindered because the manufacturer—a Boeing supplier—did not apply a protective coating over the identification mark that is required to be displayed during the manufacturing process. See FAA Press Release, "FAA Proposes $3.9 Million Civil Penalty Against The Boeing Co.," December 6, 2019, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24456

[1309] Andy Pasztor, "Boeing Finds New Software Problem That Could Complicate 737 MAX's Return," *Wall Street Journal*, January 17, 2020, accessed here: https://www.wsj.com/articles/boeing-finds-new-software-problem-that-could-complicate-737-max-return-11579290347

function did not operate properly and prevented the computers from starting.[1310] Previously, the software had been tested on simulators where no power-up problems occurred.[1311]

In April 2020, Boeing said that it needed to again update the flight control computer software to address two separate issues—one which could lead to a runaway stabilizer condition (that is not related to MCAS) and a second which could lead to disengagement of the autopilot feature during final approach.[1312] This situation raises questions as to whether the airplane's flight control computers—which date back to a 1996 design[1313]—can be programmed to reliably integrate new features, such as MCAS, that make the 737 MAX more complex than earlier versions of the airplane. The FAA issued a proposed AD for the MAX in August 2020 that includes a requirement to install updated flight control software for the flight control computer with new control laws designed to prevent erroneous MCAS activation.[1314]

Wire Bundles

Electrical wiring originally installed on 737 MAX airplanes did not meet FAA regulations for safe wire separation.[1315] Wire bundles in these airplanes were spaced too close in about 12 locations, which created the potential that arcing[1316] could occur between the bundles and damage the wires.[1317] While the possibility is remote, such damage could result in a pilot's inability to operate the electric motor that moves the airplane's stabilizer and cause the pilot to lose control of the airplane.[1318] In March 2020, according to media reports, Boeing said that it would separate the wiring bundles in its previously-manufactured airplanes before the 737 MAX returns to service. The FAA had rejected

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[1310] Ibid.
[1311] Ibid.
[1312] David Shepardson, "Boeing making new 737 MAX software updates to address computer issue," *Reuters*, April 7, 2020, accessed here: https://www.reuters.com/article/us-boeing-737max-software/boeing-making-new-737-max-software-updates-to-address-computer-issue-idUSKBN21P3K3
[1313] Darryl Campbell, "The Ancient Computers in the 737 MAX are Holding Up a Fix," *The Verge*, April 9, 2020, accessed here: https://www.theverge.com/2020/4/9/21197162/boeing-737-max-software-hardware-computer-fcc-crash
[1314] See 85 FR 47698; Docket No. FAA-2020-0686; Docket Name: 2019-NM-035-AD; Airworthiness Directives; The Boeing Company Airplanes; Notice of Proposed Rulemaking (NPRM), Federal Aviation Administration, August 6, 2020, accessed here: https://www.federalregister.gov/documents/2020/08/06/2020-17221/airworthiness-directives-the-boeing-company-airplanes
[1315] Dominic Gates, "FAA faces dilemma over 737 MAX wiring flaws that Boeing missed," *Seattle Times*, February 14, 2020, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-faces-dilemma-over-737-max-wiring-flaw-that-boeing-missed/?utm_source=referral&utm_medium=mobile-app&utm_campaign=ios
[1316] Modern commercial transport aircraft contain miles of wire that can be the source of electrical fires. One possible source of such fires is the touching of exposed metal, such as could occur when the insulation that surrounds wires becomes worn, that causes an electrical arc or spark. When electricity jumps between two conducting electrodes, such as two exposed pieces of wire, it makes an electrical arc, which is referred to as "arcing." See "Electrical Fires," *SKYbrary*, accessed here: https://www.skybrary.aero/index.php/Electrical_Fires and "What is an electrical arc?" How it Works, December 30, 2010, accessed here: https://www.howitworksdaily.com/question-of-the-day-what-is-an-electrical-arc/#
[1317] Alan Levin, "Boeing Argues It Doesn't Need to Move 737 MAX Wiring Bundles," *Bloomberg*, April 15, 2020, accessed here: https://www.bloombergquint.com/business/boeing-argues-it-doesn-t-need-to-relocate-737-max-wiring-bundles
[1318] Dominic Gates, "FAA faces dilemma over 737 MAX wiring flaws that Boeing missed," *Seattle Times*, February 14, 2020, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-faces-dilemma-over-737-max-wiring-flaw-that-boeing-missed/?utm_source=referral&utm_medium=mobile-app&utm_campaign=ios

Boeing's request to leave the bundles in place.[1319] In June 2020, Boeing reported that it had received FAA approval on the required wiring modifications and was coordinating modification efforts with the airlines.[1320] Boeing will also incorporate this wiring update in the manufacturing of future airplanes.[1321] The FAA's August 2020 proposed AD codifies the wire routing requirements to restore compliance with FAA's latest wire separation safety standards.[1322]

Fuel Tank Debris

In February 2020, Boeing discovered that some of its stored 737 MAX airplanes had foreign object debris (FOD) such as rags and tools in their fuel tanks—a condition that creates a potential safety hazard.[1323] The presence of FOD that Boeing found in the fuel tanks and other interior spaces in approximately half of the estimated 400 undelivered 737 MAX airplanes that it inspected is a production quality control issue that Boeing has also experienced on other types of aircraft that it has manufactured.[1324] For example, the U.S. Air Force has temporarily halted deliveries of Boeing's KC-46A tanker because of FOD issues twice before.[1325] As previously described, Edward Pierson, Boeing's Senior Manager for Production Support at its 737 factory in Renton, Washington, had raised concerns in 2018 about workmanship mistakes on the 737 MAX airplanes being produced at the factory that stemmed, in part, from Boeing's push to increase production.[1326] He feared that production quality issues were potentially undermining safety. The presence of FOD was the type of mistake that he worried could be brought on by an overworked, fatigued workforce. The recent reports of FOD in the 737 MAX airplanes also caused regulatory authorities to take notice. A weekly report by FAA's Seattle Aircraft Certification Office on May 11, 2020, contained an entry on "FOD in Fuel Tanks" on 737 MAX airplanes which noted that the FAA had received several messages from foreign civil aviation authorities, including the European Union Aviation Safety

[1319] Eric M. Johnson and David Shepardson, "Exclusive: Boeing to separate 737 MAX wire bundles before jet's return to service – sources," *Reuters,* March 11, 2020, accessed here: https://www.reuters.com/article/us-boeing-737max-wiring-exclusive/exclusive-boeing-to-separate-737-max-wire-bundles-before-jets-return-to-service-sources-idUSKBN20Y3E3
[1320] David Shepardson, "Boeing aims for key 737 MAX certification flight in late June: sources," *Reuters,* June 10, 2020, accessed here: https://www.reuters.com/article/us-boeing-737max/boeing-aims-for-key-737-max-certification-flight-in-late-june-sources-idUSKBN23H2O7
[1321] Ibid.
[1322] See 85 FR 47698; Docket No. FAA-2020-0686; Docket Name: 2019-NM-035-AD; Airworthiness Directives; The Boeing Company Airplanes; Notice of Proposed Rulemaking (NPRM), Federal Aviation Administration, August 6, 2020, accessed here: https://www.federalregister.gov/documents/2020/08/06/2020-17221/airworthiness-directives-the-boeing-company-airplanes
[1323] Scott Hamilton, "Boeing finds debris left in new 737 MAXes, now in storage," *Leeham News*, February 18, 2020, accessed here: https://leehamnews.com/2020/02/18/boeing-finds-debris-left-in-new-737-maxes-now-in-storage/ and Ian Duncan, "Boeing finds debris in fuel tanks of undelivered 737 Max jets," *Washington Post*, February 18, 2020, accessed here: https://www.washingtonpost.com/dc-md-va/2020/02/18/boeing-finds-debris-fuel-tanks-undelivered-737-max-jets
[1324] Andy Pasztor and Andrew Tangel, "Prosecutors, Regulators Probe Boeing 737 MAX Production Issues," *Wall Street Journal*, April 28, 2020, accessed here: https://www.wsj.com/articles/prosecutors-regulators-probe-boeing-737-max-production-issues-11588085503
[1325] Scott Hamilton, "Boeing finds debris left in new 737 MAXes, now in storage," *Leeham News*, February 18, 2020, accessed here: https://leehamnews.com/2020/02/18/boeing-finds-debris-left-in-new-737-maxes-now-in-storage
[1326] Prepared Statement of Edward F. Pierson, Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, accessed here: https://transportation.house.gov/imo/media/doc/Pierson%20Testimony.pdf

Agency, expressing concern for "Boeing Quality Issues."[1327]

Engine Panel Electrical Bonding

In June 2020, the FAA adopted an AD to require the inspection of all 737 MAX airplanes to determine the adequacy of the electrical bonding of panels on top of the LEAP-1B engines.[1328] These panels are designed to protect the encased engine wiring from the energy of High-Intensity Radiated Fields (HIRF).[1329] Defects in the manufacturing of these panels arose when workers who were polishing the engine pods at the end of the production process ground away some of the metal foil that underlies the panels.[1330] The resulting damage to the foil could prevent it from shielding the engine wiring from the electromagnetic effects of HIRF, which could potentially lead to engine power loss or the display of misleading information about propulsion parameters.[1331] The FAA AD requires that all 737 MAX airplanes undergo inspection and that any needed repairs are made before further flight.[1332]

Head-Up Guidance System Sensors

In March 2020, the FAA initiated action to impose a $19.68 million civil penalty against Boeing for the company's alleged use of sensors in Head-up Guidance Systems[1333] that had not been tested or approved as being compatible with those guidance systems.[1334] In its press release, the FAA alleged that Boeing violated Federal Aviation Regulations between June 2015 and April 2019 when it certified 791 airplanes equipped with these sensors—comprised of 618 Boeing 737 NG airplanes and 173 Boeing 737 MAX airplanes—as airworthy when they were not in compliance with their type

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[1327] "Weekly Report," Seattle ACO Branch, AIR-780, May 11, 2020, Seattle Aircraft Certification Office, Federal Aviation Administration. (On file with the Committee).

[1328] See 85 FR 38055; Docket No. FAA-2020-0091; Docket Name: 2020-NM-012-AD The Boeing Company Model 737-8 and 737-9 airplanes; Airworthiness Directives; The Boeing Company Airplanes; Final Rule, Federal Aviation Administration, June 25, 2020, accessed here: https://www.federalregister.gov/documents/2020/06/25/2020-13481/airworthiness-directives-the-boeing-company-airplanes

[1329] Aircraft are exposed to the HIRF environments that emanate, for example, from high-powered radio and television frequency transmitters, radar and satellite uplink transmitters, and large microwave communications systems. Aircraft electrical and electronic systems may be adversely affected by the electromagnetic energy generated by HIRF-producing equipment, and the failure of such systems could lead to the inability to operate the aircraft's engines and other flight controls. See: "High-Intensity Radiated Fields (HIRF) Risk Analysis," DOT/FAA/AR-99/50, Final Report, July 1999, accessed here: http://www.tc.faa.gov/its/worldpac/techrpt/ar99-50.pdf

[1330] Dominic Gates, "FAA orders inspections of all Boeing 737 MAXs to fix defect," *Seattle Times*, February 25, 2020, accessed here: https://www.seattletimes.com/business/boeing-aerospace/faa-directive-requires-boeing-to-inspect-and-fix-a-manufacturing-defect-on-all-737-maxs/

[1331] See 85 FR 38055; Docket No. FAA-2020-0091; Docket Name: 2020-NM-012-AD The Boeing Company Model 737-8 and 737-9 airplanes; Airworthiness Directives; The Boeing Company Airplanes; Final Rule, Federal Aviation Administration, June 25, 2020, accessed here: https://www.federalregister.gov/documents/2020/06/25/2020-13481/airworthiness-directives-the-boeing-company-airplanes

[1332] Ibid.

[1333] A head-up guidance system uses a transparent screen located at the flight deck window level to display flight information. The system is intended to enable "eyes-forward" flying and increase situational awareness such as by helping pilots to see through weather and low visibility conditions. For additional information on the head-up guidance system produced by Collins Aerospace for the Boeing 737, see https://www.collinsaerospace.com/-/media/project/collinsaerospace/collinsaerospace-website/product-assets/marketing/h/head-up-display/collins_evs-3600-hgs-6000_4pg_bro_final-web.pdf?rev=9088c989e09646be869197d152eb705c

[1334] FAA Press Release, "FAA Proposes $19.68 Million Civil Penalty Against The Boeing Co.," March 6, 2020, accessed here: https://www.faa.gov/news/press_releases/news_story.cfm?newsId=24716

certificate.[1335] Further, the FAA alleged that Boeing failed to follow its own business process instructions, which are in place to help prevent such situations from occurring.[1336] According to the FAA, the manufacturer of the Head-up Guidance System, Rockwell Collins, subsequently conducted the necessary testing.[1337]

On August 6, 2020, the Office of the Federal Register published FAA's proposed AD that would mandate a number of changes to the 737 MAX, including the changes described above to the flight control software that operates MCAS and to the airplane's wire bundles.[1338] This step—nearly 18 months following the FAA's order to ground the airplane—formally began the public process for establishing the requirements for the airplane's return to service.[1339]

[1335] Ibid.
[1336] Ibid.
[1337] Ibid.
[1338] See 85 FR 47698; Docket No. FAA-2020-0686; Docket Name: 2019-NM-035-AD; Airworthiness Directives; The Boeing Company Airplanes, accessed here: https://www.federalregister.gov/documents/2020/08/06/2020-17221/airworthiness-directives-the-boeing-company-airplanes
[1339] A 45-day public comment period began when FAA's proposed Airworthiness Directive published in the Federal Register.

11. Final Observations

-Final Observations-

Observations on Boeing

Restoring Boeing's Safety Focus

The beginning of this report mentioned that in 1916, soon after William Boeing established his company, he went to his airplane factory housed at the Duwamish shipyard in Seattle and began to step all over improperly sawed "spruce ribs" until they broke.[1340] He used these wooden boards to build his new airplanes. The point, as relayed from his official Boeing biography, was that he was a perfectionist and demanded that his products be of the highest quality and safe.[1341]

The Boeing Company needs to restore its reputation as a company focused squarely on safety and quality as Mr. Boeing envisioned and demanded. By heeding the horrific lessons from the MAX accidents, Boeing can and must take significant steps to create and maintain an effective, fulsome, and forthright safety culture. This would help to reinvigorate its workers' morale and public confidence that Boeing is on the road to recovery stemming from the flaws that have been exposed as a result of the MAX crashes. However, the Committee's investigation raises questions regarding Boeing's commitment to doing that or even to simply acknowledging that it made mistakes in the design, development, and certification of the 737 MAX aircraft.

What Lessons Has Boeing Learned?

Boeing says it has learned lessons and made changes since the grounding of the 737 MAX. After the Committee's October 2019 hearing on the MAX, Chair DeFazio asked follow-up questions for the record of Boeing's then-CEO Dennis Muilenburg. Among his questions, Chair DeFazio asked about efforts Boeing had taken "to ensure future airplane designs do not have similar fates."[1342]

In Boeing's response on behalf of Mr. Muilenburg, the company said that it had "initiated a review by a special board committee. That committee recommended several changes to our organization and processes designed to enhance safety culture of the company. These changes include:

(1) Creating a permanent Aerospace Safety Committee within our Board of Directors to oversee and ensure safe design, development, manufacture, maintenance, and delivery of our products and services;

(2) Creating a Product and Services Safety organization to review all aspects of product safety;

[1340] Spruce ribs are a type of wood used to build boats that Mr. Boeing used to build his first airplanes. "Biography of William E. Boeing," The Boeing Company, accessed here: https://www.boeing.com/history/pioneers/william-e-boeing.page

[1341] Ibid.

[1342] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 275, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

(3) Realigning the Engineering function within the company, so that engineers across Boeing will report directly to the Chief Engineer;

(4) Establishing a design requirements program to further facilitate the incorporation of historical design materials, data and information, best practices, lessons learned, and detailed after action reports to reinforce Boeing's commitment to continuous improvement;

(5) Enhancing our Continued Operational Safety Program to aid transparency and visibility of safety related issues; the Continued Operational Safety Program now will require the Chief Engineer's review of all safety and potential safety reports;

(6) To anticipate the needs of future pilot populations, re-examining assumptions about flight deck design and operation in partnership with our airline customers and industry members;

(7) Expanding our Safety Promotion Center for employees to learn and reflect on our safety culture and renew personal commitments to safety;

(8) Expanding our anonymous safety reporting system to strengthen safety management systems within Boeing and our supply chain;

(9) Investing in new capabilities, including enhanced flight simulation and computing, and advanced R&D for future flight decks, as well as pilot and maintenance technician training and STEM education."[1343]

The effectiveness of these organizational and procedural changes that have been recommended following its internal review will be dependent on Boeing's willingness to change. However, Boeing does not appear to have fully accepted the lessons from the MAX accidents or taken responsibility for design errors. Without that recognition it is hard to believe that Boeing will make the changes necessary to improve its safety culture.

In another question for the record following the October 2019 hearing, Chair DeFazio asked Mr. Muilenburg to identify what new information Boeing learned in the wake of the Lion Air and Ethiopian Airlines crashes that it did not already know.[1344] Chair DeFazio noted in his question that, prior to the Lion Air crash, Boeing was already aware that one of its own engineers had raised concern about MCAS relying on a single sensor, and Boeing also knew that if a pilot took more than 10 seconds to respond to an uncommanded MCAS activation, the result could be "catastrophic."[1345]

[1343] Ibid.
[1344] Ibid., p. 279
[1345] Ibid.

Instead of acknowledging in its reply that Boeing learned post crashes that its design was flawed, or that it had made mistakes, Boeing blamed industry-wide assumptions regarding pilot response times:

> In designing MCAS, Boeing relied on well-accepted, industry-wide assumptions in evaluating how pilots would react to the uncommanded activation of MCAS for any reason, including erroneous AOA. Those assumptions proved not to be accurate in these accidents. Accordingly, we now know that there is a greater risk from unintended activation of MCAS due to erroneous AOA data than we originally thought. Our system redesign addresses this issue.[1346]

Except as the Committee's investigation has shown, Boeing **did**, in fact, have information that those industry-wide assumptions were wrong. Boeing knew this because it had internal test data it had acquired as early as November 2012 that its own test pilot took more than 10 seconds to respond to uncommanded MCAS activation during a test scenario in a flight simulator, a condition the pilot found to be "catastrophic[.]"[1347] Boeing clearly realized the significance of a delayed response to MCAS activation because it described this "catastrophic" test result in six separate Coordination Sheets about MCAS that were completed from 2015 to 2018.[1348] What is less clear is why Boeing never shared this important data with the FAA, its customers, or 737 MAX pilots.

Boeing's reluctance to admit mistakes is also evident in its response to another question for the record from Rep. Sharice Davids in which she asked if Boeing had taken any disciplinary action against employees who were aware that the AOA Disagree alert was not functioning on the majority of MAX airplanes prior to the Lion Air crash and failed to take appropriate steps to inform the FAA or Boeing's customers.[1349] In its reply, Boeing said the priority was returning the 737 MAX to service:

[1346] Ibid.

[1347] Ibid.

[1348] Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision B, July 8, 2015, TBC T&I 191227 - TBC T&I 191232 at TBC T&I 191231 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision C, October 19, 2015, TBC T&I 253262 - TBC T&I 253268 at TBC T&I 253267 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision D, March 30, 2016, accessed at p. 164 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf; Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision E, July 5, 2016, TBC T&I 129776 - TBC T&I 129782 at TBC T&I 129782 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision F, December 20, 2017, TBC T&I 037449 - TBC T&I 037457 at TBC T&I 037457 (On file with Committee); Boeing Coordination Sheet, "737MAX Flaps Up High Alpha Stabilizer Trim (MCAS) Requirements," No. Aero-B-BBA8-C12-0159, Model: 737-MAX (-7/8/9), Revision G, June, 11 2018, accessed at p. 174 here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1349] Hearing titled, "The Boeing 737 MAX: Examining the Design, Development, and Marketing of the Aircraft," Committee on Transportation & Infrastructure, U.S. House of Representatives, 116th Congress, First Session, October 30, 2019, p. 281, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

> As Mr. Muilenburg testified, our current focus as a Company is on doing everything possible to ensure the safe return of the MAX to service. We owe this to our customers and the flying public. That said, once the MAX is safely back in service, the time will come to consider further questions of accountability. And Boeing will not hesitate to hold people accountable, where appropriate.[1350]

This response indicates that Boeing remains focused first and foremost on returning the MAX to service instead of focusing on accountability and fixing past mistakes and processes that led to the design, certification, and production of an unsafe airplane.

Observations on the Federal Aviation Administration (FAA)

Restoring FAA's Safety Focus

For its part, the MAX crashes show that the FAA must develop a more aggressive certification and oversight structure to ensure safe aircraft designs. Traditionally, the FAA has been the primary leader of the world's civilian aviation authorities, but questions raised about the FAA's role in the 737 MAX crisis have punctured its reputation as the gold standard in aviation safety and international civil aviation authorities have clashed with the FAA over the 737 MAX.[1351] For example, the European Union Aviation Safety Agency (EASA) has raised concerns about the lack of a third AOA sensor on the 737 MAX. EASA has reportedly insisted that changes be made to the MAX to address its concerns, and its insistence on such changes has reportedly caused tension between EASA and the FAA.[1352] In addition, Transport Canada may lag behind the FAA in approving the 737 MAX to return to service based on its demands to give pilots the option to disable the "stick shaker"—a warning mechanism that noisily vibrates the airplane's yoke when the airplane is at risk of entering a stall—to reduce the risk of pilot distraction in the event of erroneous activation of the safety feature.[1353] As regulators have historically presented a united front in public, the reported disagreements between foreign authorities and the FAA provides insight into the reputational damage suffered by the agency in the wake of the 737 MAX crashes.

What Lessons Has FAA Learned?

Following the 737 MAX crashes, numerous studies, including the JATR, NTSB, and the DOT's Special Committee, have generated a multitude of findings and recommendations to improve aviation safety. These recommendations largely focused on how the FAA could improve its certification processes and enhance its oversight of Boeing and other aircraft manufacturers. It remains to be seen, however, how the FAA will address these issues and whether it will fully embrace these recommendations.

[1350] Ibid.
[1351] Siddharth Philip, Julie Johnsson, Charlotte Ryan, and Kait Bolongaro, "Boeing 737 MAX Return Outside U.S. Seen Slowed by Regulators," *Bloomberg News*, August 11, 2020, accessed here: https://www.bnnbloomberg.ca/boeing-737-max-return-outside-u-s-seen-slowed-by-regulators-1.1478539 and Dominic Gates, "Foreign regulators demand substantial new changes to Boeing 737 MAX flight controls," *Seattle Times*, June 24, 2020, accessed here: https://www.seattletimes.com/business/boeing-aerospace/foreign-regulators-demand-substantial-new-changes-to-boeing-737-max-flight-controls
[1352] Ibid.
[1353] Ibid.

More broadly, in his prepared testimony for the Committee's December 2019, hearing, FAA Administrator Dickson acknowledged several issues the FAA needs to address to improve its certification process, including:

- moving toward a more holistic versus transactional, item-by-item approach to aircraft certification—taking into account the interactions between all aircraft systems and the crew;
- integrating human factors considerations more effectively throughout the design process, as aircraft become more automated and systems more complex; and
- ensuring coordinated and flexible information flow during the oversight process.[1354]

Improving Safety Cultures

To benefit from the recommendations that have been directed to them, both Boeing and the FAA will need to address fundamental issues within their respective ranks concerning the roles and responsibilities of Authorized Representatives (ARs), and remove barriers that prevent them from acting as the eyes and ears of the FAA with the **singular** goal of ensuring the safety of the flying public. The current structure of the Organization Designation Authorization (ODA) program makes that difficult. It creates inherent conflicts-of-interest and too often, as this report has revealed, hinders ARs from consistently representing the interests of the FAA. Boeing's corporate interests often influence the actions of ARs and present barriers to enhancing aviation safety for the benefit of the flying public. These ARs need to have, and know they have, wide latitude and clear channels of communication with the FAA so that they can raise safety concerns and work in concert with the FAA to help address these concerns together. This report has shown that this is not currently the case.

In November 2016, at the height of the 737 MAX development process, Boeing conducted an internal survey of its ARs regarding "undue pressure." The results showed that 97 percent of those surveyed said they understood the process for reporting "undue pressure," and 90 percent felt comfortable raising issues of "undue pressure" with their management. However, the results also clearly pointed to significant problems with the current ODA structure. In the survey, for example, 39 percent of those responding said they had experienced "undue pressure" and 29 percent were "concerned about consequences" if they reported acts of "undue pressure." In addition, 80 percent of those who said they had experienced undue pressure reported having experienced it on more than one occasion.[1355]

[1354] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, p. 14, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1355] Boeing presentation, "Undue Pressure: Key Learnings and Next Steps," The Boeing Company, November 2016, accessed here at p. 145: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

The FAA's own internal survey of its "safety culture" was also troubling. A recent internal survey of FAA employees in the Aviation Safety Organization (AVS)[1356] conducted in November and December 2019, found that 54 percent of FAA employees in the Aircraft Certification Service (AIR)—a part of AVS—said the FAA does **not** appropriately delegate certification activities to external FAA designees.[1357] The survey found 43 percent of AVS-wide respondents felt the same way.[1358] In addition, 56 percent of AIR employees believed there was too much external influence on the agency and that it was having an impact on safety.[1359] Another 49 percent of all AVS-wide respondents said they believed "safety concerns/incidents" will not be addressed by the agency.[1360] Additionally, nearly half of the survey respondents "**disagreed** that FAA makes data-driven decisions about safety regardless of external pressure,"[1361] *(emphasis in original).*

The agency's waning safety culture stands as a significant barrier to its capacity to learn lessons from the MAX tragedies and make fundamental organizational improvements. This safety culture survey demands close scrutiny and inspection by FAA's top leaders. It mirrors many of the Committee's findings and raises serious questions about the agency's ability to fulfill its safety mission. According to the FAA's survey, a key takeaway is that "AVS senior leadership's response to and management of industry pressure is at the heart of the organization's core safety culture challenges: lack of trust, inconsistent accountability, FAA role confusion, and the perception that AVS is moving further away from its safety mission."[1362]

FAA's Cooperation with the Committee

Chair DeFazio and Subcommittee on Aviation Chair Larsen originally wrote to the FAA on April 1, 2019, with a records request relating to the design, development, and certification of the 737 MAX, and related issues.[1363] The request sought 13 separate categories of information. Since then, the FAA has provided the Committee with more than 42,000 pages of records. While this is significant, the Committee has received nearly 550,000 pages of records from Boeing, for comparison.

The FAA records provided by DOT have been extremely important to the Committee's investigation. However, as was noted in the Executive Summary to this report, DOT's production of records has been inexplicably slow and is seemingly incomplete. The DOT has yet to communicate to the Committee its progress toward a **full and complete** response to the Committee's records request. Rather, the DOT has repeatedly and consistently refused to provide

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[1356] See "Safety Culture Assessment Report," Federal Aviation Administration, Aviation Safety Organization (AVS), prepared by The MITRE Corporation, (DRAFT) February 28, 2020, (hereafter referred to as "FAA Safety Culture Assessment Report") (On file with the Committee), and "Safety Culture Survey Findings," Federal Aviation Administration, Aviation Safety Organization (AVS), prepared by The MITRE Corporation, February 28, 2020, (hereafter referred to as "FAA Safety Culture Survey Findings") (On file with the Committee).
[1357] "FAA Safety Culture Survey Findings," pp. 8 and 85.
[1358] Ibid., p. 85.
[1359] Ibid., p. 44.
[1360] Ibid., p. 23.
[1361] FAA Safety Culture Assessment Report, p. 32.
[1362] Ibid., p. 7.
[1363] "As Part of Investigation into Boeing 737 MAX Certification Process, Committee Sends Records Requests to FAA, Boeing," Press Release, Committee on Transportation and Infrastructure, April 1, 2019, accessed here: https://transportation.house.gov/news/press-releases/as-part-of-investigation-into-boeing-737-max-certification-process-committee-sends-records-requests-to-faa-boeing

updates on the status of this and related requests.[1364] As previously noted in this report, the DOT's actions in its response to oversight requests have frustrated Committees and Chairs in both houses of Congress who have experienced remarkably similar situations.[1365]

The DOT's lack of full and thorough cooperation with the Committee regarding its investigation of the 737 MAX inevitably raises questions about whether DOT will take the steps necessary to renew FAA's focus on safety, be transparent about these steps with the public, and recommit to improving its oversight of Boeing. This report concludes the bulk of the Committee's work on the 737 MAX investigation. However, if the Committee becomes aware of additional issues that warrant follow-up based on new records it receives from the FAA, DOT, or others, the Committee will take those issues seriously and pursue them as warranted.

Time for a Culture Change

Both Boeing and the FAA share responsibility for the development and ultimate certification of an aircraft that was unsafe. Both must learn critical lessons from these tragic accidents to improve the certification process, and the FAA must dramatically amplify and improve its oversight of Boeing. While the changes that the FAA and Boeing have proposed will be the start of a long process, changing the fundamental cultural issues that led to an environment that permitted Boeing to build, and FAA to certify, a technologically faulty aircraft will take much longer.

At the Committee's December 2019 hearing on the MAX, Dr. Mica Endsley, a human factors expert and former Chief Scientist of the U.S. Air Force noted the importance of cultural changes at both the FAA and Boeing:

> There has been considerable discussion here today and also previously in the press about concerns about safety culture at both Boeing and the FAA that sort of underlie a lot of the failures we saw in good process and ended up being in good design.

[1364] In June 2019, DOT/FAA informed the House Committee on Transportation and Infrastructure that, regarding the Committee's investigation of the 737 MAX, it had between 92,265 and 592,915 potentially responsive emails to just a few of the Committee's April 1, 2019, records requests. The FAA acknowledged it had 592,915 emails with the term "MCAS" or "AOA Sensors," for instance, between March 2014 and April 25, 2019. This included 338,074 emails with the terms "MCAS" or "AOA Sensors" and the terms "development" or "testing" or "fielding" or "certification." For the period between March 2014 and October 29, 2018, the number of emails that the FAA identified with the term "MCAS" or "AOA Sensors" was 234,425. In relation to the terms "MCAS" or "AOA Sensors" and the terms "development" or "testing" or "fielding" or "certification," for that same time period, the FAA had identified 92,265 emails. See: "FAA Responses to Follow-Up Questions from House T&I Staff," June 7, 2019, BATES Number FAA-T&I-000192. In addition, in November 2019, in order to help DOT manage the scope of the Committee's requests and at the specific suggestion of DOT, the Committee provided DOT with a list of 13 specific searches of 27 current and former FAA officials. The Committee has received several productions of records related to this request. However, DOT has been unable or unwilling to inform the Committee which of these 13 searches have been performed or completed or which of the 27 individuals' records have been searched. The Committee remains unaware of the status of its records requests to FAA regarding the 737 MAX despite repeated requests to DOT about this issue.

[1365] Prepared Statement, Chairman Roger Wicker, Hearing titled: "Examining the Federal Aviation Administration's Oversight of Aircraft Certification," Senate Committee on Commerce, Science & Transportation, June 17, 2020, accessed here: https://www.commerce.senate.gov/2020/6/examining-the-federal-aviation-administration-s-oversight-of-aircraft-certification

> The FAA Administrator and Boeing have made a number of announcements of things they are going to do to try to fix that, and we? are glad to see that, but changing culture is really hard. You can't just give a one-shot and it is done. It is something you have to do every day.
>
> It has a lot more to do with actions than with words, and so, the importance of really following up on those actions of taking safety issues very seriously, of reprioritizing safety with regard to production and cost in schedule, those changes are going to require a lot of continued interaction by management….[1366]

Do Things Right and Do the Right Thing

One of the fundamental canons for engineers is that they hold paramount the safety, health, and welfare of the public.[1367] Or as Texas State University Engineering Professor Karl Stephan says, "A good engineer both does things right, and does the right thing."[1368] In the case of the 737 MAX, unfortunately, Boeing failed to meet both criteria. It did not do things "right" when it designed MCAS, for instance. It failed to build in essential redundancies by permitting MCAS to rely on a single AOA sensor. It allowed MCAS to activate repetitively, although at least one Boeing engineer had raised concerns about that capability. And it did not appropriately address the question of faulty AOA data and the negative implications for MCAS because a Boeing engineer falsely assumed that MCAS would not allow that to happen and "shut down." That did not happen in either of the MAX crashes.

Furthermore, Boeing did not do the "right thing" when it removed references to MCAS from the pilot's Flight Crew Operations Manual (FCOM). Without question, it was not right for Boeing to fail to share with the FAA Boeing's own test data showing that it had taken a test pilot more than 10 seconds to respond to uncommanded MCAS activation, and the test pilot believed the condition was "catastrophic[.]" Nor did Boeing do the "right thing" when it became aware that the AOA Disagree alert was not functioning on more than 80 percent of the 737 MAX fleet and then failed to alert the FAA, its customers, and MAX pilots while it continued to both manufacture and deliver an estimated 200 airplanes with this known nonfunctional component.

In the weeks after the Lion Air crash, Boeing defended its development and certification of MCAS to the FAA, writing that there was "no process violation or non-compliance" regarding the inconsistencies in the system's development and Boeing's actions, including (1) removing reference to MCAS from the FCOM, (2) determining "repeated unintended MCAS" activation to be no worse than a single unintended activation, (3) determining the loss of one AOA sensor followed by erroneous readings from the other AOA sensor to be extremely remote and not analyzing this

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[1366] Hearing titled, "The Boeing 737 MAX: Examining the Federal Aviation Administration's Oversight of the Aircraft's Certification," Committee on Transportation and Infrastructure, U.S. House of Representatives, 116th Congress, First Session, December 11, 2019, pp. 149-150, accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg40697/pdf/CHRG-116hhrg40697.pdf

[1367] "Code of Ethics for Engineers," National Society of Professional Engineers, accessed here: https://www.nspe.org/sites/default/files/resources/pdfs/Ethics/CodeofEthics/NSPECodeofEthicsforEngineers.pdf

[1368] Karl Stephan, "About the Engineering Ethics Blog" *Engineering Ethics Blog*, accessed here: http://engineeringethicsblog.blogspot.com/p/about-engineering-ethics-blog.html

scenario in its failure assessments, and (4) not reassessing failure analyses following the MCAS design change.[1369]

The FAA's own draft review of MCAS in the wake of the Lion Air crash also found no "non-compliances" with FAA regulations on the part of Boeing.[1370] The fact that multiple technical design missteps or certification blunders were deemed compliant by the FAA points to a critical need for legislative and regulatory reforms. [1371] That Boeing was able to show that its new transport category commercial aircraft met the FAA's certification criteria, yet was involved in two fatal crashes within the span of just two years and two days after the FAA granted certification, is disconcerting. The FAA's aviation oversight system failed in dramatic fashion. This sentiment is underscored by Tommaso Sgobba, Executive Director of the International Association for the Advancement of Space Safety (IAASS), who recently observed: "The Boeing B-737 MAX accidents represent a major failure of the aviation regulatory system…."[1372]

Indeed, producing a compliant aircraft that proved unsafe should have been an immediate wake-up call to both Boeing and the FAA that the current regulatory system that certified the MAX is broken. Unfortunately, serious questions remain as to whether Boeing and the FAA have fully and correctly learned the lessons from the MAX failures.

The Once Great Engineering Firm

The beginning of this report quoted Harry Stonecipher, the Chief Executive Officer of McDonnell Douglas who became the President and Chief Operating Officer of Boeing, who in 2004 told the *Chicago Tribune*: "When people say I changed the culture of Boeing, that was the intent, so it's run like a business rather than a great engineering firm." It is unfortunate that many current and former Boeing employees the Committee has spoken to during this investigation believe Boeing has succeeded in meeting that goal. They understand they once worked for a great engineering firm, and many hope that they will again in the future. But they realize this will happen only if Boeing begins to refocus its engineering expertise on building great, safe aircraft, and that this endeavor will be a long-term challenge.

[1369] Boeing letter to FAA, "Subject: Submittal of MCAS Development and Certification Overview," RA-19-00256, March 1, 2019, TBC-T&I 130073–130074, 130075–130117, at pp. 178-179, 180-201 accessed here: https://www.govinfo.gov/content/pkg/CHRG-116hhrg38282/pdf/CHRG-116hhrg38282.pdf

[1370] See "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019, p. 8, 12 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020.) and DOT Office of Inspector General, "Timeline of Activities Leading to the Certification of the Boeing 737 MAX 8 Aircraft and Actions Taken After the October 2018 Lion Air Accident," Report No. AV2020037, June 29, 2020, pp. 32-233, accessed here: https://www.oig.dot.gov/sites/default/files/FAA%20Oversight%20of%20Boeing%20737%20MAX%20Certification%20Timeline%20Final%20Report.pdf

[1371] "737-8 MAX Maneuvering Characteristics Augmentation System Oversight Report," Prepared by: FAA AIR-860 BASOO, Boeing Aviation Safety Oversight Office (BASOO), Federal Aviation Administration (FAA), February 8, 2019, p. 8, 12 (Draft). (Reviewed remotely "in camera" via access to FAA website by Committee Staff on May 1, 2020.)

[1372] Tommaso Sgobba, "B-737 MAX and the crash of the regulatory system," *Journal of Space Safety Engineering,* Volume 6, Issue 4, December 2019, Pages 299-303, accessed here: https://www.sciencedirect.com/science/article/abs/pii/S246889671930093X

考研资料：数学、英语、政治、管综、西综、法硕等（整合各大机构）
英语类：四六级万词班专四专八雅思等
财经类：初级会计、中级会计、注册会计、高级会计、税务师、会计实操、证券从业、基金从业、资产评估、初级审
公务员：国考、省考、事业单位、军队文职、三支一扶微信 2270291360
银行：银行招聘、笔试、面试
教师资格：小学、中学、教师招聘面试
建筑：一建、二建、消防、造价
法考：主观题、客观题
多平台网课：涵盖职场、办公技能、编程、文案写作、情感心理、穿搭技巧、理财投资健身减肥摄影技术等优质内容
精选资料：Excel 教程、PPT 模板、简历模板、PS 教程、PPT 教程、素描、烹饪、小语种、CAD 教程、PR 教程、UI 课程、自媒体、写作、计算机二级、钢琴、Python、书法、吉他、kindle 电子书、演讲.....持续更新中...
押题：提供考前冲刺押题（初级会计、中级会计、注册会计、一建、二建、教资、四六级、证券、基金、期货等等），麻麻再也不用担心我考不过了。
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两小时搞定毛概马原思修近代史纲	高数(微积分)+线性代数+概率论	素描 0 基础入门教程
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11. Final Observations

This report's main investigative findings point to a company culture that is in serious need of a safety reset. Boeing has gone from being a great engineering company to being a big business focused on financial success. Continuing on the same path it followed with the 737 MAX, where safety was sacrificed to production pressures, exposes the company to potentially repeating those mistakes and to additional reputational damage and financial losses. One of the first steps on a new path is understanding and acknowledging the problems that **did** occur, the technical mistakes that were made, and the management missteps that led to the 737 MAX tragedies and the preventable death of 346 people.

However, the Committee's investigation leaves open the question of Boeing's willingness to admit to and learn from the company's mistakes. In a transcribed interview with Committee staff, Keith Leverkuhn, the former senior-most official on Boeing's 737 MAX program, who is now Vice President of Supply Chain Propulsion for Boeing Commercial Airplanes, appeared unable or unwilling to either take responsibility for any of the problems that occurred on the MAX program or to even acknowledge that any problems existed at all.

> **T&I Committee staff:** In light of the two crashes and the fact that the MAX has been grounded for more than a year, would you consider the development of the MAX a success?
>
> **Mr. Leverkuhn:** Yes, I would. ….
>
> …. I do challenge the suggestion that the development [of the 737 MAX] was a failure.[1373]

Several weeks before this report was finalized, multiple news stories suggested that Boeing was endeavoring to change the name of the 737 MAX to the 737-8 in an effort to combat the indelible image problems now surrounding the aircraft.[1374] If the Committee's investigation offers any lessons for Boeing, it is that a name change and a public relations effort will not address the cultural issues at Boeing that hampered the safety of the 737 MAX in the first place and ultimately led to two fatal accidents and the death of 346 people. A name change may help confront a public relations problem, but only a genuine, holistic, and assertive commitment to changing the cultural issues unearthed in the Committee's investigation at both Boeing and the FAA can enhance aviation safety and truly help both Boeing and the FAA learn from the dire lessons of the 737 MAX tragedies.

[1373] Committee staff transcribed interview of Keith Leverkuhn, former Vice President and General Manager of the 737 MAX program, Boeing Commercial Airplanes, May 19, 2020.

[1374] See: Chris Woodyard, "Boeing may be tackling 737 Max's PR problem with a new name," *USA Today*, August 19, 2020, accessed here: https://www.usatoday.com/story/news/2020/08/19/boeing-737-max-jetliners-appears-getting-new-name/5612691002; David Slotnick, "Boeing may be dropping the 'Max' from the name of its troubled jet, calling the latest version the 737-8," *Business Insider*, August 19, 2020, accessed here: https://www.businessinsider.com/boeing-737-max-name-change-rebrand-2020-8 and Dan Reed, "MAX No More? For Some Reason Boeing Won't Admit It, But It's Changing The Name Of Its New Generation Of 737s," *Forbes*, August 24, 2020, accessed here: https://www.forbes.com/sites/danielreed/2020/08/24/max-no-more-for-some-reason-boeing-wont-admit-it-but-its-changing-the-name-of-its-new-generation-of-737s/#20dc4753619b